Research Paper

Research on Quantitative Analysis Method of Street Space Quality Evaluation

Illustrated by the case of Wuhan City Centre

Huihui YAN, Wuhan Planning & Design Institution, China
Runzhi HUANG, non, China
Yunming Geng, Wuhan Planning & Design Institution, China

Abstract

With the continuous development of technical means, information technologies such as big data and artificial intelligence have gradually become one of the core technical means of planning and design. Applying AI and big data to evaluate street space has also become one hot spot in recent years. However, there are few studies on the street space quality of Wuhan based on new technology, and especially there is almost no evaluation system that combines planning technology and information technology. This study employs big data, traditional planning data and current status survey data, combined with artificial intelligence, ArcGIS spatial analysis and spatial syntax and other analytical techniques, to propose a comprehensive system for evaluating street space quality. This paper selects an area in the central city of Wuhan for the case study on the quality evaluation system, and accordingly provides an analytic idea for the planning and construction of streets, so as to guide the implementation of street-related projects and planning.

Keywords

Street space quality, evaluation, quantitative analysis

1. Research overview

As the most basic urban place for public activities and most closely related to urban residents, street space is an important spatial carrier of the city (Jin, 2017; Chen & Liu, 2020). Over the years, domestic and foreign scholars have conducted extensive and in-depth research on the quality of urban street space. Early research tend to evaluate street space quality based on street conditions. For instance, Lynch (1984), Jane (2006) and Alexander *et al*. (1977) point out the necessary conditions of a high-quality, vibrant and pedestrian-friendly street mainly include street safety, functional diversity, public space, street scale and key elements. However, they never propose a complete system for street space quality evaluation.

Nowadays information technologies have become one essential technique mean for planning and design. Despite AI and big data been more frequently utilised in street space evaluation (Li & Long, 2018; Wang *et al*., 2018; Dai & Hua, 2019; Long & Zhou, 2016), few studies on the street space quality of Wuhan are found based on new technology, neither evaluation system that integrates planning technology with information technology. This article employs multi-source data that combines new technologies and traditional planning methods to evaluate the quality of street space, meanwhile puts forward an analytical idea for street planning and construction, further offering a technical path to guide the future evaluation of street-related implementation projects and planning.

This paper consists of evaluation system establishment, empirical research and results summary. The evaluation system establishment refers to selecting the most suitable quantitative indicators for street quality evaluation of Wuhan City to form a complete quality evaluation formula via project literature learning, investigation and research. For the empirical research, we select an area in Wuhan city centre to conduct the case study on the quality evaluation formula. Moreover, the last section include analysis and explanation of the evaluation results, summary out of the results, and technical problems and barriers in the analysis process. It should be particularly pointed out that in this paper, the research object at the material spatial level of street is defined as the following: 1) main functional facilities, including motor vehicle lanes, bus lanes, motor vehicle parking belts, non-motor vehicle lanes, sidewalks, etc.; 2) ancillary functional facilities, including street greening, street furniture, municipal facilities, isolation facilities, pedestrian crossings, safety facilities, etc.; 3) spatial interfaces, including facade shapes, colours, and ancillary facilities along the street. The data adopted majorly comprise traditional planning and design drawing data, street view image data of Internet map open platform, POI data of Internet open platform, and current situation survey data.

2. Establishment of the evaluation system for street space quality

2.1. Selection of street space quality evaluation indicators

There are three main considerations for indicator selection in this study. First, the indicators ought to be commonly used and have city-representativeness and operability. These indicators are expected to reflect the outstanding current problems of the city, especially the key points in related compilation and implementation projects that are closely related to street quality. Secondly, the indicators should reflect the street issues that street users are most concerned about, and explore the street space elements that users most care about. Finally, the selected indicators are capable of quantitative analysis and research through the existing emerging informatisation planning technology and traditional planning technology, and therefore facilitate to drawing final conclusion.

In the first step, we sorted out the literature on street space quality. By comprehensively analysing the basic urban design quality quantitative model proposed by Ewing and Clemente (2013), the street space quality measurement model proposed by Ye *et al*. (2019), the street space reconstruction evaluation model designed by Tang *et al*. (2016), and the analysis index of public space quality on commercial street established by He *et al*. (2018), indicators that appear more frequently include street green viewing rate, sky rate, open rate, building coverage rate, attachment rate, pedestrian space scale, transparency, aspect ratio, etc. Meanwhile, to be coherent with the characteristics of Wuhan city, we also sorted out street planning projects recently prepared by Wuhan. Such as Wuhan City Street Design Guidelines, Wuhan City Road Total Element Planning and Design Guidelines, Hankou Concession District Street System Planning, Wuhan Urban Design Management Element Database, etc. 12 key indicators were found with urban characteristics among these projects, including pedestrian space scale, non-motorised vehicles and slow-moving system integrity, building front area space scale, full-calibre citizen street facilities (barrier-free access, recreation and entertainment facilities for young and old), building aspect ratio, micro-public space layout and corresponding facility layout, street furniture, traffic and street function coordination, traffic safety facility configuration, attachment rate, green looking ratio, and the number of entrances and exits along the street.

In order to reflect the most concerned street elements by street users, we referred to the online and offline user questionnaire survey on ‘idea street’ conducted by Wuhan City Street Design Guidelines. The citizens believe that the characteristics of high-quality streets ordered by importance include street walking safety, pleasant spatial scale, good street management and maintenance, layout of street facilities and furniture, street vitality, comfortable street environment, unique street temperament and high accessibility. Thus, for the indicator selection, we pay special attention to the scale of pedestrian space, aspect ratio, street furniture, transparency, number of shops, green vision, fun and street style. In addition, the obtained indicators should be able to be translated by various existing technologies for quantitative analysis. Indicators for which data cannot be obtained or evaluation methods cannot be set are to be removed from the indicator system.

Ultimately, this study employs 15 indicators via collating the indicators obtained from classic literature and actual cases (see Table 1).

	First class classification	Evaluation indicators	Evaluation techniques
1	Street functional space	Pedestrian space width	2D plane data
2		Road accessibility	Space syntax
3		On-street parking facilities	Research data
4	Street space facilities	Spatial continuity of walkway	Research data
5		Spatial continuity of barrier-free access	Research data
6		Street furniture	Street view image
7	Street visual perception	Aspect ratio	Street view image
8		Sky open rate	Street view image
9		Attachment rate	2D plane data
10		Green looking ratio	Street view image
11		Building coverage rate	Street view image
12		Transparency	Research data
13	Street style perception	Spatial interest	Street view image
14		Star store density	Big data
15		Street openness rate	Street view image

Table 1. Evaluation indicators. Source: Created by the authors.

2.2. Establishment of evaluation system for street space

After identification, we assigned weights to the indicators by comparing relevant literature and research, and discussing with experts in the planning industry in Wuhan (refer to Table 2). Next, we set up corresponding evaluation standards for each indicator, with the evaluation results expressed in scores. Details of the criteria are discussed in the following subsections.

	First class classification	Evaluation indicators	Weight coefficient
1	Street functional space	Pedestrian space width	0.068
2		Road accessibility	0.075
3		On-street parking facilities	0.023
4	Street space facilities	Spatial continuity of walkway	0.071
5		Spatial continuity of barrier-free access	0.056

6		Street furniture	0.083
7	Street visual perception	Aspect ratio	0.071
8		Sky open rate	0.075
9		Attachment rate	0.056
10		Green looking ratio	0.071
11		Building coverage rate	0.068
12		Transparency	0.068
13	Street style perception	Spatial interest	0.075
14		Star store density	0.064
15		Street openness rate	0.075

Table 2. Evaluation system. Source: Created by the authors.

2.2.1. Street functional space evaluation standard

1) Evaluation standard of pedestrian space width

For the evaluation of pedestrian space width of the current street, we referred to the setting of the pedestrian space width (facility zone, pedestrian passage area and total building width) of the ideal street in the domestic large city street design guidelines. The standards are demonstrated as in Table 3.

Street types	Evaluation interval		
	Good (9’)	Fair (5’)	Poor (1’)
Traffic street	Both sides>5M	5M>both sides>2.5M; One side<5M	Both sides<2.5M
Comprehensive /commercial street	Both sides>5M	5M>both sides>2.5M; One side<5M	Both sides<2.5M
Life street	Both sides>2M; Laneway>1.5M	2M>both sides>1.5M; One side<1M	Both sides<1.5M
Landscape street	Both sides>5M	5M>both sides>2.5M; One side<5M	Both sides<2.5M

Table 3. Pedestrian space width evaluation standards. Source: Created by the authors.

2) Road accessibility evaluation standards

As the space syntax proposed by Hillier & Hanson (1984) makes a complete and comprehensive analysis of street accessibility, we applied space syntax software to analyse 800-metre walkability and 3200-metre non-motorised and motorised accessibility, with the standards shown in Table 4.

Accessibility	Evaluation interval				
	Very poor (1’)	Poor (3’)	Fair (5’)	Good (7’)	Excellent (9’)
800M	<240	240-282	282-308	308-348	>348
3200M	<1697	1697-1876	1876-2060	2060-2400	>2400

Table 4. Accessibility evaluation standards. Source: Created by the authors.

3) Evaluation criteria for on-street parking facilities

In this section, the streets are sorted by hierarchy and width for assessment on whether it is suitable for on-street parking. Roads with on-street parking set up in accordance with the standards (refer to Table 5) are recorded as up to standard (scored 9 for excellent), and those fail to comply with the standards are regarded as not up to standards (scored 1 for very poor).

Road types		Space width of roadway (M)	On-street parking setting
Urban expressway		/	No parking
Urban arterial road		/	No parking
Special historic and landscape road		/	No parking
General road	Two-way	>12	Allow two-sided parking
		8-12	Allow one-sided parking
		<8	No parking
	One-way	>9	Allow two-sided parking
		6-9	Allow one-sided parking
		<6	No parking
Alley		>9	Allow two-sided parking
		6-9	Allow one-sided parking
		<6	No parking

Table 5. On-street parking facility standards. Source: Created by the authors.

2.2.2. Street space facilities evaluation standards

1) Evaluation criteria for spatial continuity of walkway and barrier-free access

Based on the current channel space continuity, streets with 100%-set channels are regarded as completely continuous, referring to excellent spatial continuity, while streets of which 60% equipped with passage are considered as most continuous. Besides, those with less than 60% being set with passage are classified as partially continuous, indicating less continuity (see Table 6).

Evaluation interval	Excellent (9’)	Good (7’)	Fair (5’)	Poor (3’)	Very poor (1’)
Passage setting	Both sides completely continuous	Both sides mostly continuous	Both sides partially continuous; one-side completely continuous	One-side partially continuous	No passage

Table 6. Evaluation standards for spatial continuity of walkway and barrier-free access. Source: Created by the authors.

2) Street furniture evaluation standards

The evaluation of street furniture focuses on garbage bins, seats, and art ornaments on street. The garbage bins are evaluated in accordance with relevant street design guides, referring to the spacing requirements of bins on different street types (see Table 7). Since there are no fixed standards for leisure seats and art ornaments, the streets with seats and ornaments are recorded as seat-compliant and ornament-compliant respectively, evaluated in conjunction with the garbage bin compliance. Within the street section, if there are two or more items of street furniture that meet the standard, it is regarded as excellent, scored 9 points; if with one up-to-standard item, it is considered as fair, scored 5 points; and if no item meets the standard, it is marked as poor with 1 point.

Street types	Traffic street	Life street	Comprehensive /commercial street	Landscape street	Others
Spacing requirements (M)	200-400	50-100	50-100	100-200	50-100

Table 7. Garbage bin setting standards. Source: Created by the authors.

2.2.3. Street visual perception evaluation standards

1) Aspect ratio evaluation standards

The street aspect ratio is one of the essential methods to evaluate the street scale. Different aspect ratios bring different spatial perceptions to street users. Ashihara (2006) pointed out that different functions and types of streets should have different optimal aspect ratios. Accordingly, we employed AI to recognise the three-dimensional building model on streets of different types while complying with aspect ratio evaluation in related research and planning. The corresponding standards are summarised as in Table 8.

Street Types	Evaluation interval		
	Good (9’)	Fair (5’)	Poor (1’)
Commercial	0.66-2	0.33-0.66, 2-3	Other
Life	0.66-2	0.33-0.66, 2-3	Other
Traffic/comprehensive/landscape	1.0-2.0	0.66-1, 2-3	Other

Table 8. Aspect ratio evaluation standards. Source: Created by the authors.

2) Attachment rate evaluation standards

Attaching rate = length of street wall elevation ÷ length of building control line × 100%. Evaluating the attachment rate is a common method to judge the degree of street enclosure. A comprehensive, commercial and living street should emphasise a higher degree of enclosure, namely a higher attachment rate control. Table 9 demonstrates the attachment rate criteria on various street types.

Street types	Evaluation interval		
	Good (9’)	Fair (5’)	Poor (1’)
Traffic street	55-65%	45-55%, 65-75%	<45%, >75%
Comprehensive/commercial street	>80%	70-80%	<70%
Life street	>70%	60-70%	<60%
Landscape street	55-65%	45-55%, 65-75%	<45%, >75%

Table 9. Attachment rate evaluation standards. Source: Created by the authors.

3) Green looking ratio evaluation standards

Orihara (2006) divides the green looking ratio into five levels: streets with green looking ratio of less than 5%, 5%-15%, 15%-25%, 25%-35% and over 35% respectively provide very poor, poor, fair, good and excellent street green perception (Xiao *et al*., 2018). Correspondingly, we confirmed the criteria as shown in Table 10.

Evaluation interval	Excellent (9')	Good (7')	Fair (5')	Poor (3')	Very poor (1')
Green looking ratio	<5%	5%-15%	15%-25%	25%-35%	>35%

Table 10. Green looking ratio evaluation standards. Source: Orihara, N. (2006), A Study on Evaluation of Green Landscape-Consideration on Green Evaluation Method for Good Landscape Formation.

4) Transparency evaluation standards

The design of ground floor of building facade along the street requires the combination of virtual and real, avoiding large-scale solid walls, to encourage interaction between shops and users (Luo, 2016). In this study, standards for transparency varies on street functions, with transparency requirements of life service streets are lower than other types (see Table 11).

Street types	Evaluation interval	
	Up to standard (9')	not to standard (1')
Comprehensive/commercial street	≥60%	<60%
Life street	≥30%	<30%
Traffic street	≥60%	<60%
Landscape street	≥60%	<60%

Table 11. Transparency evaluation standards. Source: Created by the authors.

5) Sky open rate evaluation standards

The sky open rate refers to the proportion of the area of the sky relative to the total field of view in a position (Wuhan Planning Research Institute & CitoryTech, 2018). It is used to describe the visibility of the sky at the position and is a manifestation of the transparency of the street. There are different rate requirements for streets of different functions. We applied AI to identify street scene images, and further, interpreted the sky open rate that to be evaluated according to the standards illustrated in Table 12.

Evaluation interval	Excellent (9')	Good (7')	Fair (5')	Poor (3')	Very poor (1')
General street	<5%	5-10%	10-20%	20-30%	≥30%
Landscape street	≥30%	20-30%	10-20%	5-10%	<5%

Table 12. Sky open rate evaluation standards. Source: Created by the authors.

6) Building coverage rate evaluation criteria

Similarly, building coverage rate refers to the proportion of the area of a building relative to the entire field of view at a certain location (Ibid.). It indicates the visibility of building at certain location and the degree of street enclosure. We used the same method above and the evaluation criteria are shown as Table 13.

Evaluation interval	Very poor (1')	Poor (3')	Fair (5')	Good (7')	Excellent (9')
General street	<20%	20-30%	30-40%	40-50%	≥50%
Landscape street	≥50%	40-50%	30-40%	20-30%	<20%

Table 13. Building coverage rate evaluation standards. Source: Created by the authors.

2.2.4. Street style perception evaluation standards

1) Spatial interest evaluation standards

The AI was also applied to gain insight into interesting street space photos. We then used the machine to score and interpret the collected street view images, simulating manual evaluation on the street interest level (refer to Table 14).

Evaluation interval	Very poor (1’)	Poor (3’)	Fair (5’)	Good (7’)	Excellent (9’)
Spatial interest	<2	2-5	5-6.5	6.5-8	≥8

Table 14. Spatial interest evaluation standards. Source: Created by the authors.

2) Evaluation criteria of star store density

In the research on Shanghai Huaihai Road by Chen & Zhao (2014) and on Shanghai Nanjing West Road by Xu & Kang (2014), they all point out that if the density of shops reached 7 per 100 metres, it can best balance the flow of people and the vitality of shops. Since the indicator data were from the open-source big data of Dianping, certain inaccuracies in the location and information of stores exist, and we only employed stores with a review of 3 stars for the evaluation with criteria shown in Table 15.

Evaluation interval	Very poor (1’)	Poor (3’)	Fair (5’)	Good (7’)	Excellent (9’)
Star store density (per hundred metre)	<2	2-4	4-5	5-7	≥7

Table 15. Star store density evaluation standards. Source: Created by the authors.

3) Street openness rate evaluation standards

In terms of street openness rate, we still applied AI for an in-depth study on the collected street scene images and subsequently scored by machines. Unlike the traditional evaluation that simply refers to the degree of openness, the index for this research (see Table 16) comprises not only the high sky open rate and low building visibility, but whether the street experience brings citizens with a pleasant and cheerful experience.

Evaluation interval	Very poor (1’)	Poor (3’)	Fair (5’)	Good (7’)	Excellent (9’)
Openness rate	<2	2-4	4-6	6-8	≥8

Table 16. Street openness rate evaluation standards. Source: Created by the authors.

3. Empirical study on the quality of streets in Wuhan central city

3.1. Scope of research

The study area reaches Huangpu Avenue in the north, Yiyuan Road and Xinma Road in the south, Yanjiang Avenue in the east, and Jiefang Avenue in the west, with a land area of 1.87 square kilometres (see Figure 1). There is relatively high density of streets in that area, covering a variety of functional streets, including traffic arterial roads with elevated roads and rail transit lines, commercial representative streets, landscape streets along the river, and streets serving citizens' life. Meanwhile, as the area situates in the original concession area of Hankou, there integrate old and new buildings, and the roads are in different conditions while the road space is greatly differentiated, contributing to high research value.

Figure 1. Empirical research area. Source: Google Map, modified by the authors.

3.2. Street data sample setting

There exist 31 streets in the research area if sorted by name. Among them, according to road hierarchy, there are 2 express roads, 2 main roads, 4 secondary roads, 26 branch roads, and 4 public passages. Besides, when divided by road function, there comprise 4 traffic roads, 3 comprehensive commercial roads, 1 landscape road, and 24 life service roads (refer to Table 17).

Street name	Street form	Street hierarchy	Street function

Jiefang Ave	Along the river	Main city expressway	Traffic
Jinghan Ave	Along the river	Main city secondary roads, branch roads	Traffic
Zhongshan Ave	Along the river	Main city secondary roads, branch roads	Comprehensive
Changchun St	Along the river	Main city branch road, public passage	Life service
Yanjiang Ave	Along the river	Main road	Landscape
Jiefang South Rd	Along the river	Main city branch road	Life service
Huangpu Ave	Perpendicular to the river	Main city expressway	Traffic
Lugouqiao Rd	Perpendicular to the river	Main city secondary roads, branch roads	Commercial
Dalian Rd	Perpendicular to the river	Main city branch road	Life service
Haomengling Rd	Perpendicular to the river	Main city branch road	Life service
Zhangzizhong Rd	Perpendicular to the river	Main city branch road	Life service
Xinxing St	Perpendicular to the river	Main city branch road	Life service
Shenyang Rd	Perpendicular to the river	Main city branch road	Life service
Shanhaiguan Rd	Perpendicular to the river	Main city branch road	Life service
Chenhuaimin Rd	Perpendicular to the river	Main city branch road	Life service
Liuhe Rd	Perpendicular to the river	Main city branch road	Life service
Jiefang Park Rd	Perpendicular to the river	Main city branch road	Life service
Wufu Lane	Perpendicular to the river	Main city branch road	Life service
Wufu Rd	Perpendicular to the river	Main city branch road	Life service
Siwei Ln	Perpendicular to the river	Main city branch road	Life service
Linzhi Rd	Perpendicular to the river	Main city branch road	Life service
Siwei Rd	Perpendicular to the river	Main city branch road	Life service
Sanyang Rd	Perpendicular to the river	Main road	Traffic/commercial
Eryao Ln	Perpendicular to the river	Public passage	Life service
Eryao Rd	Perpendicular to the river	Main city branch road	Life service
Jianshe St	Perpendicular to the river	Main city branch road	Life service
Gongan Rd	Perpendicular to the river	Public passage	Life service
Yiyuan Ln	Perpendicular to the river	Public passage	Life service
Xinma Rd	Perpendicular to the river	Main city branch road	Life service
Yiyuan Rd	Perpendicular to the river	Main city branch road	Life service

Table 17. Classification of streets within the study area. Source: Created by the authors.

In order to facilitate the calculation and analysis of data samples, we segmented the streets into smaller sections (Badrinarayanan, et al., 2015). Comprehensively considering the greater road network density and the more diverse road conditions in the area, the basic section of the road was divided by road intersections, while the longer roads without intersections were cut according to the main entrance of the main building and the entrance of the public passage. Finally, there formed 118 road analysis sections (see Figure 2), with each road section as the smallest unit of this analysis.

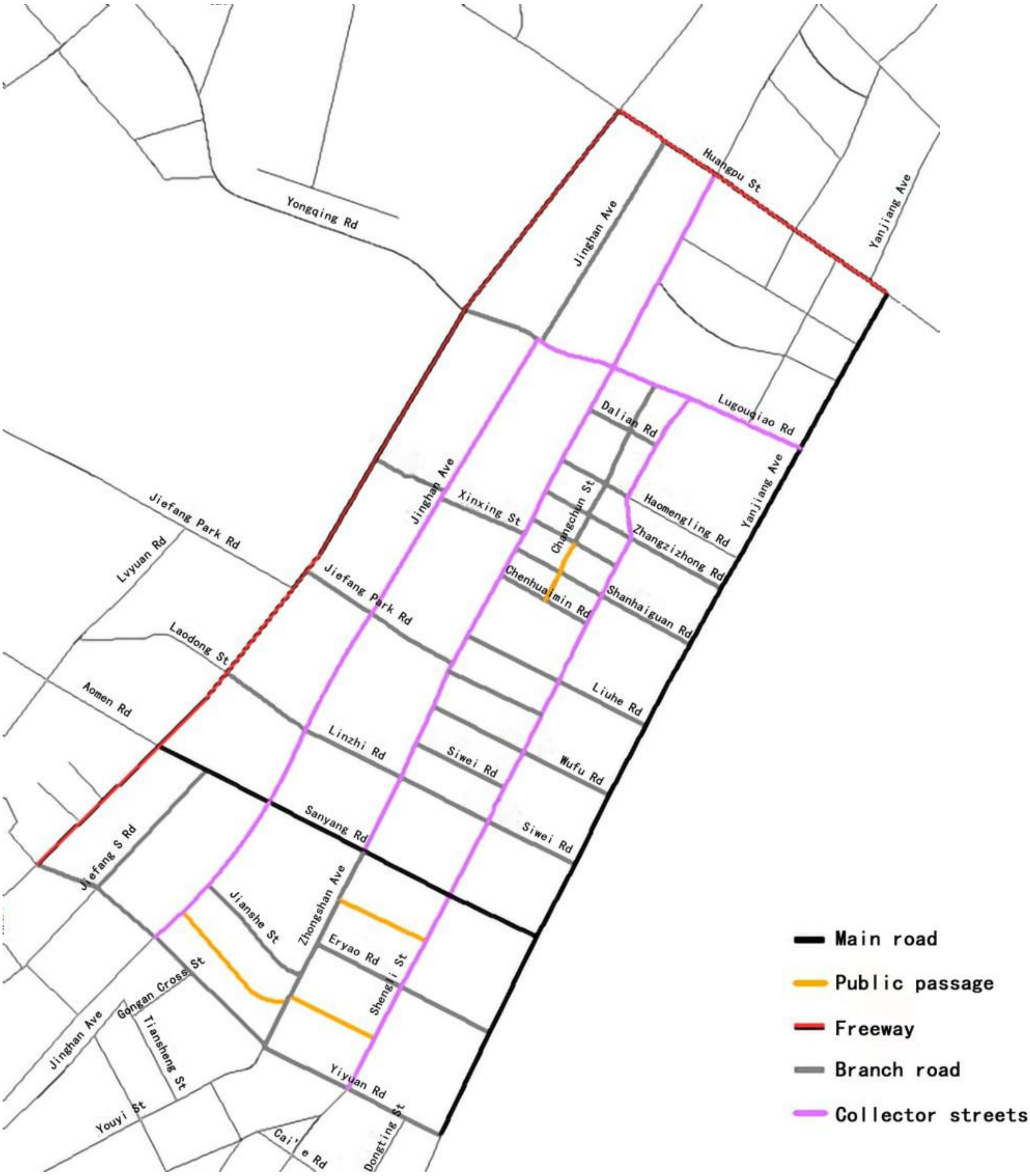

Figure 2. Street sections within the study area. Source: Created by the authors.

3.3. Evaluation and analysis of street space quality

3.3.1. Evaluation and analysis of street space function

As illustrated in Figure 3, the street sections with better walking space generally belong to high-grade roads and are relatively newly built, while the old urban branch roads, such as Dalian Road, Haomengling Road, Shenyang Road and Chen Huaimin Road, obviously provide not-wide-enough walking space, leading to poor walking experience. As for the accessibility, Jiefang Avenue and its intersecting Xinxing Street, Jiefang Park Road and Sanyang Road are significantly more accessible, indicating that higher-grade roads and their intersecting roads have certain advantages in accessibility. In addition, on-street parking in the area is overall in an ideal state, with only a few older road sections fail to meet the standards.

Figure 3. Evaluation of street space function indicators. Source: Created by the authors.

3.3.2. Evaluation and analysis of street space facilities

Referring to Figure 4, the walkways within the study area connect well in general that contributes to a relatively complete pedestrian traffic system. However, the continuity of barrier-free passages varies greatly. Despite continuous and complete barrier-free passages on high-grade roads, the urban branch roads are of poor continuity. Besides, most streets lack a complete layout of street furniture facilities.

Figure 4. Evaluation of street space facilities. Source: Created by the authors.

3.3.3. Evaluation and analysis of street visual perception

Figure 5 demonstrates evaluation results of the 6 visual-perception-related indicators. The aspect ratio and attachment rate of life service streets perpendicular to the river overall perform well. These streets are of a more pleasant and comfortable spatial scale and a more suitable sense of street enclosure. The result of the green looking ratio indicates that the non-expressways along the river are equipped with better greening configuration, yet the scenic riverside avenue needs to be enhanced. In terms of transparency, both sides of the two expressways, Huangpu Avenue and Jiefang Avenue, require improvement, while the narrower laneways, such as Yiyuan Lane and Eryao Lane, also lack transparency. Further, while the sky open rate turns to be overall good, the result of building coverage rate is unsatisfactory except Yanjiang Avenue, and the results vary significantly among different sections of the same road.

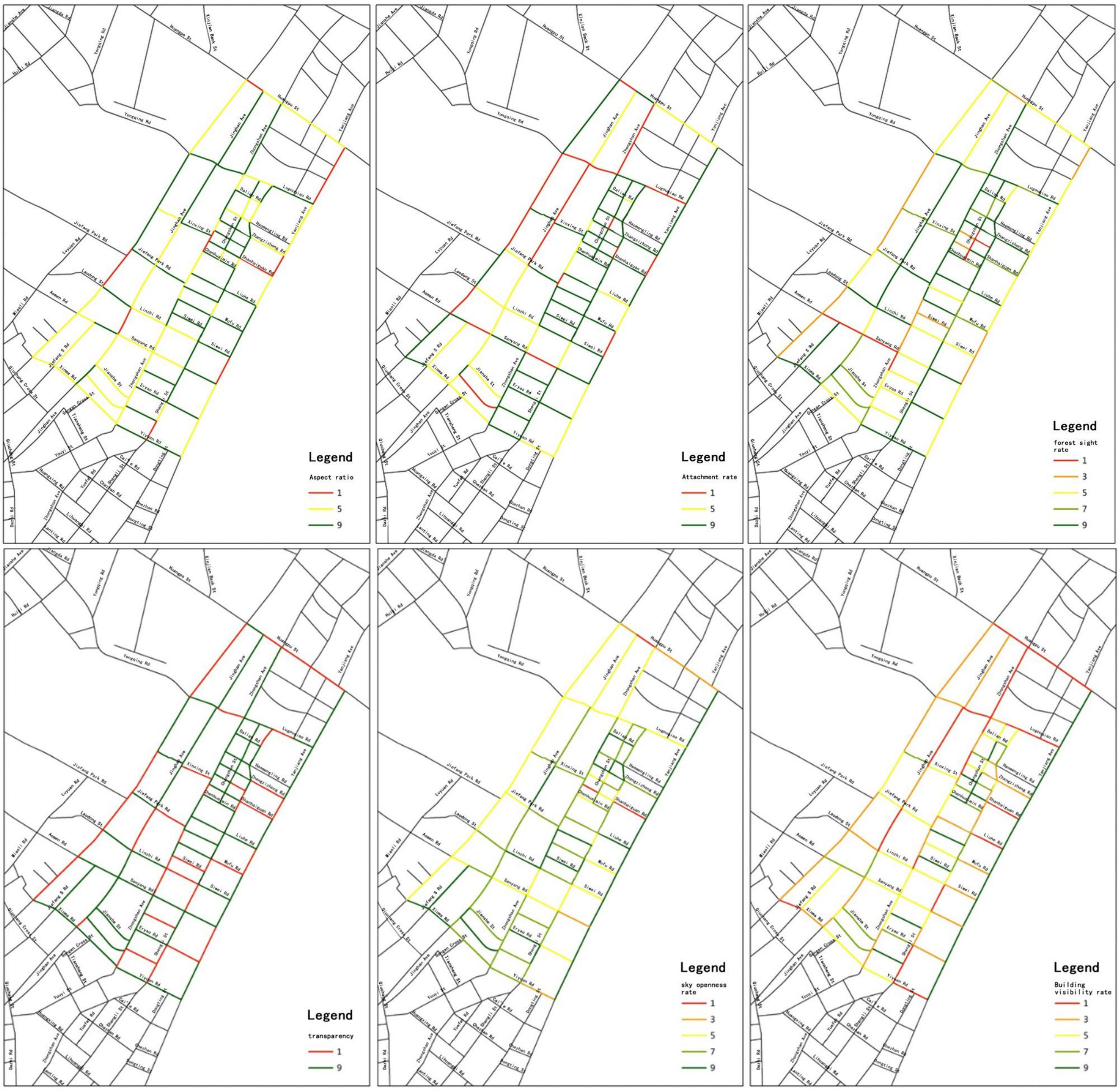

Figure 5. Evaluation of street visual perception indicators. Source: Created by the authors.

3.3.4. Street style perception evaluation standard

As shown in Figure 6, streets within the area provide users with a pleasant experience and satisfaction in openness in general, whereas the star stores are still not dense enough. It is noticeable that the results of some narrow lanes completely opposite between spatial interest and openness. In common parlance, exactly due to narrowness, such life service streets tend to create a strong living and market atmosphere, where there also locate more star stores.

Figure 6. Evaluation of street style perception indicators. Source: Created by the authors.

4. Conclusion

This study formulates a street space quality evaluation system based on multi-source data analysis methods, and through the empirical research on an area in Wuhan city centre, it is confirmed that this system is effective to evaluate urban street space quality. The research applies emerging data recognition technology and data research methods to analyse street images with related planning data. These technical methods contribute to more efficient analysis, facilitating inspection and evaluation of the function and spatial quality of streets from more diversified angles. Meanwhile, the AI technology applied greatly liberates human resources while interprets data more accurately and objectively. Furthermore, multi-source data resources make the analysis no longer limit at the material-space-based objective data, but extend to non-material street space. Nowadays urban planning has entered the era of inventory planning, with the demand for renovation and renewal of old cities increasing in planning. While the evaluation of spatial function and quality of old blocks and streets has become a key focus, efficient and reliable analysis techniques for street functions and spatial quality, along with analysis ideas for various data, will play a significant role in future planning practices.

It is undeniable this indicator system is still imperfect in view of the complexity of urban street space. Above all, there lack relevant evaluations for buildings on both sides of the street space, including cleanliness and characteristics evaluation of the building facade, evaluation of the conformity of building colour with codes, evaluation of the area of the building front, etc. Secondly, there is no assessment on street environmental tidiness, such as AI evaluation of street neatness, assessment on street odour, air quality data, etc. Besides, more detailed street facility evaluations are not included as well, like safety evaluation, sustainable facility evaluation, facility compound utilisation evaluation, etc. Consequently, follow-up research requires focus on two aspects. The first is to promote further evaluation and learning of AI, such as evaluation of street environment tidiness, street safety evaluation, and a more detailed street facility identification system. The second is to further collect and sort out various data. On the one hand, big data technology can be utilised to track and monitor environmental quality data, crowd and traffic data, data on various smart city facilities, etc. On the other hand, it is also helpful to apply new scientific and technological resources to improve traditional data acquisition paths, such as establishing data and resource sharing cloud platform, collecting data from multiple aspects and improving the efficiency of obtaining microdata.

5. References

Alexander, C., Ishikawa, S., Silverstein, M., Jacobson, M., Fiksdahl-King, I. and Angel, S. (1977) *A pattern language.* 1st edn. New York: Oxford University Press.

Ashihara, Y. (2006) *The Aesthetic Townscape.* 1st edn. Tianjin: Baihua Literature and Art Publishing House.

Badrinarayanan, V., Kendall, A. & Cipolla, R., (2015) 'SegNet: A deep convolutional encoder-decoder architecture for image segmentation', *IEEE Transactions on Pattern Analysis & Machine Intelligence*, 2015(11), p1-14.

Chen, F. & Liu, T.D. (2020) 'The brief analysis of humanized design in street space - Take Aoshan-Qinghecheng block in Optics Valley Central City as an example', Open Journal of Transportation Technologies, 9(3) [online]. Available at: https://m.hanspub.org/journal/paper/35876 (Accessed: 05 August 2020)

Chen, Y. & Zhao, X.H. (2014) 'Research on ground-floor interfaces along streets from the perspective of pedestrians: A case study of huaihai road in Shanghai', *City Planning Review*, 2014(6), p24-31.

Ewing R. & Clemente, O. (2013) *Measuring Urban Design: Metrics for Livable Places.* 1st edn. Washington, DC: Island Press.

He, H., Chen, Y. & Lin, X.W. (2018) 'Research on identification and evaluation of influencing factors of public space quality of commercial streets based on open data - Taking Chuhe Han Street and Zhongshan Avenue in Wuhan as examples', *Urbanism and Architecture*, 2018(6), p26-34.

Hillier, B. & Hanson, J., (2019) *The Social Logic of Space.* 1st edn. Beijing: China Architecture & Building Press.

Jane, J. (2006) *Death and life of great American cities.* 2nd edn. Nanjing: Yilin Press.

Jin, S. (2017) 'Street walkability - Design requirements and planning suggestions for vigorous streets in Shanghai', Shanghai Urban Planning Review, 2017(1) [online]. Available at: http://guihuayun.com/api/app/nav_weixin_detail.php?wid=33002 (Accessed: 05 August 2020)

Li, X.J., Zhang, C.R., Li, W.D. *et al*. (2015) 'Assessing street-level urban greenery using Google street view and a modified green view index', *Urban Forestry & Urban Greening*, 14(3), p675-685.

Li, Z. & Long, Y. (2018) 'An analysis on variation of quality of street space in shrinking cities based on dynamic street view pictures recognition: A case study of Qiqihar', *Urbanism and Architecture*, 2018(6), p21-25.

Long, Y. & Zhou, Y. (2016) 'Quantitative evaluation on street vibrancy and its impact factors: A case study of Chengdu', *New Architecture,* 2016(1), p52-57.

Luo, K.D. (2016) 'What will Shanghai's future streets look like? - Shanghai Street Design Guidelines has been released', *360Doc* [online]. Available at: http://www.360doc.com/content/16/1021/20/35494618_600305972.shtml (Accessed: 05 August 2020)

Lynch, K. (1984) *Good city form.* 2nd edn. Cambridge: MIT Press.

Orihara, N. (2006) ‘A study on evaluation of green landscape - Consideration on green evaluation method for good landscape formation’, *Seasonal research report of UR*, 142(03), p48-57.

Tang, J.X., Long, Y., Zhai, W. *et al*. (2016) ‘Measuring quality of street space, its temporal variation and impact factors: an analysis based on massive street view pictures’, *New Architecture*, 2016(5), p110-115.

Wuhan Planning Research Institute & CitoryTech (2018) ‘Deep learning, street view recognition | Quantitative research on Wuhan City street view’, *Urban Data Union* [online]. Available at: http://udu.org.cn/thread-35-1-1.html (Accessed: 05 August 2020)

Xiao, X., Wei, Y.K., Li, M. (2018) ‘The method of measurement and applications of visible green index in Japan’, *Urban Planning International*, 33(2), p98-103.

Xu, L.Q., Kang, Q. (2014) ‘The relationship between pedestrian behaviors and the spatial Features along the ground-floor commercial street: The case of west Nanjing Road in Shanghai’, *Urban Planning Forum*, 2014(3), p104-111.

Ye, Y., Zhang, S.X., Zhang, X.H. *et al*. (2019) ‘Human-scale quality on streets: A large-scale and efficient analytical approach based on street view images and new urban analytical tools’, *Urban Planning International*, 34(1), p18-27.