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An Urban Renewal Strategy Based on the Fuzzy Analytic Hierarchy Process (FAHP) — A Case Study of the Qiaoxi Historic District of the Hangzhou Section of the Canal

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Abstract: The Grand Canal is a miracle of world engineering and one of the most representative world cultural heritages in China. In the second half of the 20th century, due to the serious pollution of the canal industry and the adjustment of the industrial structure brought about by the development of Hangzhou, the Hangzhou section of the canal is facing pollution remediation, and the Coastal space is facing the migration and decline of industrial areas, and is in the transition stage from industrialization to consumption service. Therefore, it is urgent to find a transformation and regeneration mode and build an industrial heritage corridor. In the 1990s, the Hangzhou municipal government carried out a large-scale renovation of the canal, and at the beginning of this century, the coastal industrial heritage, including the protection of historical areas, has made remarkable achievements, but there are still many problems to be solved. Given the demand for the urban renewal in the Hangzhou section of the Grand Canal, this study uses the Qiaoxi Historic District as a case study and applies the Fuzzy Analytic Hierarchy Process (FAHP) to establish an evaluation system at four different levels. These levels are: 'overall planning and regulations', 'space and planning', 'format and positioning', and 'building and place'. In addition to that, it aims to establish an analysis and evaluation models for each node that can be used for optimization strategies. Finally, it is applied to the urban renewal of 'place and building' in Qiaoxi Historic District. The evaluation method used in this paper provides not only an important enlightenment and data support for the urban renewal of the Qiaoxi Historic District, but also a methodological guidance for the urban renewal of Hangzhou.

Keywords: Fuzzy Analytic Hierarchy Process (FAHP), Evaluation System, Urban Renewal, Qiaoxi Historic District

1. Introduction

Qiaoxi Historic District is located on the western side of the Hangzhou Gongchen Bridge, and the eastern side of the Beijing-Hangzhou Grand Canal. It is a relatively mature historical landscape and industrial heritage area along the coast. In the late 20th century, the industrial pollution along the canal was serious, and the canal confronted with pollution remediation and entered a key stage for consumer service. In this regard, the main research works on the urban renewal, such as that of Zhang Yidan, who proposed six revitalization and development strategies including creating cultural business, from the perspective of Hangzhou's cultural values [1]. Zhang Jingjing and Zhu Demin proposed a multi-dimensional evaluation system for the waterfront industrial heritage and optimization strategies for transportation, architecture, and public space [2, 3]. Zhang et al. conducted a case interpretation and deductive analysis of the craft art museums from the aspects of their functional orientation, morphological protection, and display methods [2]. Guided by the continuation of the urban memory, they put forward a framework of the basic factor layer and the guarantee factor layer and carried out the orientation role of the four main bodies of the urban renewal. Nevertheless, there are still numerous problems needed to be solved. For example, the research work mainly focuses on the analysis of the concepts, methods, and protection modes of the existing transformation cases [4-7]. There are many studies on the

planning, architectural design methods [8-10], and visions but relatively fewer studies on the evaluation system of management, protection modes, characteristics of transformation relics, and the refining of transformation regeneration into strategies. The renewal of the Qiaoxi Historic District also faces the same problem.

Based on the Fuzzy Analytic Hierarchy Process (FAHP), this paper establishes the evaluation model and the evaluation system of the whole life cycle, aiming at the transformation and regeneration of the Qiaoxi Historic District. It also suggests some improvement strategies for the renewal of the historical district in Qiaoxi from the aspects of overall planning and regulations, space and planning, format and positioning, and buildings and places. This research can provide development and construction references for the overall planning of Hangzhou.

2. Research Area and Methodology

2.1. Research Area

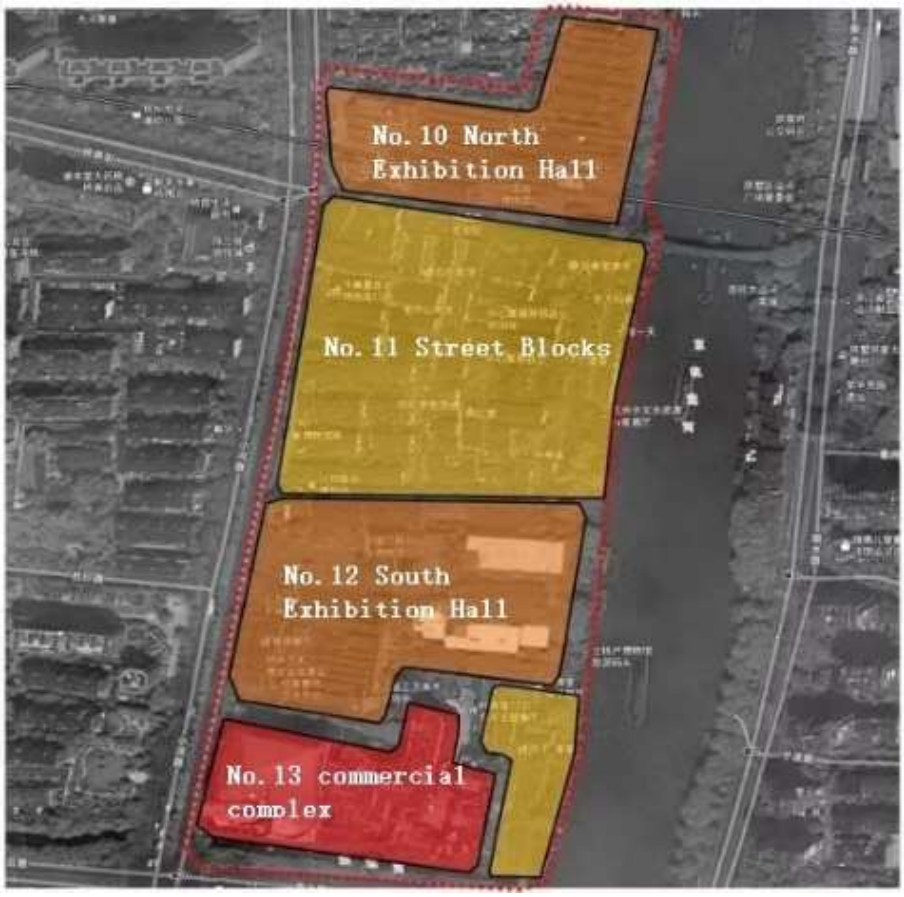

Figure 1. *Qiaoxi Historic District.*

The historical district of Qiaoxi in Hangzhou, which is considered in this study, includes the Gaojia Garden from the north, Qiaoxi Zhijie from the east, Dengyun Road from the south, and the Xiaohe Road from the west. Additionally, the central commercial and aboriginal settlements, the north-south exhibition area, and the south-side Tianyang commercial complex are included and shown in nodes (10), (11), and (12) in Figure 1. The industrial heritage in this region is considered rich.

2.2. Research Methodology

Generally, the evaluation of the urban renewal complex problems mainly includes subjective and objective weighting methods. The subjective weighting method includes the Delphi method, the Analytic Hierarchy Process, and the Fuzzy Comprehensive Evaluation Method [11]. The objective weighting method includes the Cluster Analysis method and the Principal Component method. Different evaluation methods have their unique advantages and disadvantages, which makes them suitable for different evaluation objects [12]. Since the evaluation of the Qiaoxi Historic District involves several complex components, the importance of each influencing factor is not the same. If the direct scoring evaluation method is used, the subsequent multi-dimensional analysis that is needed to obtain the solution strategy will be very complicated. Assuming that the majority of the influencing factors in the evaluation system can be accurately classified and compared, FAHP can be used to establish the

evaluation system [13-16].

Firstly, the set of evaluation factors is established for the district through investigation and analysis. Then, the importance of each evaluation factor is determined by consulting industry experts, and the fuzzy judgment matrix is constructed. The real weight of each factor in the evaluation system is obtained by the fuzzy operation, and the evaluation model is established. Finally, the evaluation model is used to evaluate and analyze all the professional and non-professional groups. The professional groups are evaluated by scoring, and the results are used as the main evaluation basis. The non-professional groups are evaluated by collecting the results through direct questionnaires and interviews as an auxiliary reference for evaluation.

3. Establishment of a Fuzzy Analytic Hierarchy Process Evaluation Model

3.1. Establishment of the Factor Set

According to the requirements of the Analytic Hierarchy Process, through screening and reconstruction, the system of the Qiaoxi Historic District includes four first-level evaluation factors and twenty second-level evaluation factors, as shown in table 1. The first-level evaluation factor set is represented by U_1 = (A, B, C, D), and the second-level evaluation factor set is represented by U_2 = (A_i, B_j, C_m, D_n). The relations between the first-level and the second-level factors is shown in Figure 2.

Table 1. *Evaluation Factors of the Qiaoxi Historic District in Hangzhou.*

Evaluation Factor	
First level factor U_1	**Secondary factor U_2**
A: Integration and regulation	A_1: Development model; A_2: Subjects of authority and responsibility; A_3: Protection scope and object; A_4: Integrity of the regulatory guidelines; A_5: Brand and event.
B: Space and planning	B_1: Spatial cohesion; B_2: Corridor continuity; B_3: Traffic accessibility; B_4: Style coordination.
C: Format and positioning	C_1: Positioning accuracy; C_2: Modality sharing; C_3: Representation of the heritage value.
D: Architecture and site	D_{11}: Public space settings; D_{12}: Place transportation; D_{13}: Place culture; D_{14}: Site waterfront relations; D_{15}: Site ecology; D_{21}: Architectural openness; D_{22}: Architectural culture; D_{23}: Construction waterfront relations.

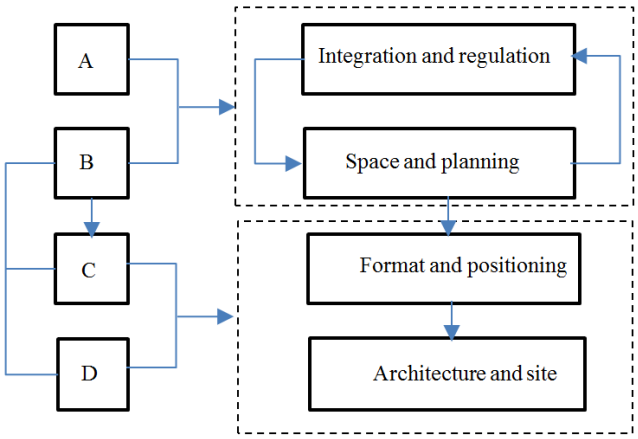

Figure 2. *The relationship between primary and secondary factors.*

3.2. Establishment of the Evaluation Sets

The evaluation set $V = (V'_1, V'_2, V'_3, V'_4)$ is established to evaluate the results. The set of neutron elements represents the evaluation level and can be divided into five distinct levels, namely V' = (very poor, poor, medium, good, and very good).

3.3. Determination of the Evaluation Weight

Industry experts in the field of urban renewal were invited to score and construct a fuzzy judgment matrix for each factor set. The main steps of the FAHP are:

(1) Determination of the Factor Scale

For simplicity, taking the four grades as an example, the importance of the elements is defined as ' Extremely important, very important, important, and not very important'. a_{ij} is used to represent the ratio of the relative importance of the elements, where the higher value of this ratio implies that the elements are of significant importance. The following relation exists: $a_{ij} = 1;\ i = j = 1,2,\cdots,n$.

(2) Development of the Judgment Matrix

The factors are judged and compared according to the structural model. Taking the n dimension as an example, the judgment matrix (A) is constructed, as shown in equation (1). The fuzzy judgment matrix of the factor set u_1 and u_2, for the first and second factors, can be established as A_1 and A_2, respectively.

$$A=\begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \cdots \\ \frac{1}{a_{n1}} & \frac{1}{a_{n2}} & \cdots & 1 \end{bmatrix} \quad (1)$$

(3) Construction of a fuzzy consistent judgment matrix

A Fuzzy consistent judgment matrix can improve the fault tolerance and minimize the subjective influence on the outcomes. The fuzzy consistent judgment matrix can be obtained from matrix A as follows:

$$A_f = (A_{ij})_{n\times n} \quad (2)$$

where, $A_{ij} = \frac{A_i - A_j}{2(n-1)} + 0.5, \quad A_i = \sum_k^n a_{ik}\ (i=1,2,\cdots,n)$

(4) Determining the factor weights

According to the fuzzy consistent judgment matrix, the weight set w_i = (w_{i1}, w_{i2},$\cdots w_{in}$) of the secondary influencing factors can be obtained using:

$$w_{ij} = \frac{1}{n} - \frac{n}{4a(n-1)} - \frac{1}{2a(n-1)} \sum_{k=1}^{n} A_{ij} \quad (3)$$

where, $j = 1, 2, \cdots, n$ and $a \geq 2(\text{n-1}) / 5$. The minimum value of the parameters ensures that the weight is unique for each factor. Similarly, the first-level influencing factor weight set can be obtained.

(5) Establishment of a judgement matrix

The relevance between the factor set and the evaluation set can be represented by the evaluation matrix. In general, the problem with the evaluation index for urban renewal is that it is difficult to quantify. In order to solve this problem, the associated relationship of each factor on the evaluation set is investigated by an expert evaluation method. The factor set evaluation matrix is composed of several factors according to the evaluation results.

$$\boldsymbol{R} = \begin{bmatrix} r_1 \\ r_2 \\ \vdots \\ r_n \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix} \quad (4)$$

where, $r_{ij}, i = 1,2,\cdots,n; j = 1,2,\cdots,n$ represents the relation between the i elements and the j elements in the evaluation set.

(6) Establishing the Fuzzy Comprehensive Evaluation

The weight of the obtained two-level factor set and the evaluation matrix are used together to evaluate the upper-level factors. The evaluation results are then used to comprehensively evaluate the first-level factors to obtain a comprehensive evaluation of the target indicators. The fuzzy operator is used to transform the factor weight and the evaluation matrix, and the results Vi and Vi can then be used as the evaluation results of the upper-level factors.

$$V_i = (v_{i1}, v_{i2}, \cdots, v_{in}) = w_i \circ R_i = (w_{i1}, w_{i2}, \cdots, w_{in}) \circ \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix}, i = 1,2,\cdots n \quad (5)$$

The weighted average model is:

$$b_{ie} = \sum_{j=1}^{n} w_{ij}\, r_{je}, j = 1,2,\cdots n \quad (6)$$

After obtaining the secondary comprehensive evaluation results, the factor weight is then used to obtain the primary comprehensive evaluation results using the fuzzy operation.

4. Evaluation Results and Update Strategy

Table 2 shows the fuzzy evaluation results of the professionals for the Qiaoxi Historic District. From the evaluation results, the Qiaoxi District has a relatively high evaluation at the level of 'Integration and regulation' and 'Space and planning', but there is still much room for improvement at the level of 'Format and positioning' and 'Architecture and site'. Some of the common problems are:

(1) Coordinating and planning: There are no specific regulations and guidelines that can be followed for further upgrading the district. In addition to that, the main business of the district is not well-diversified, the market vitality is not fully stimulated, and the benefit is low. Furthermore, there are only a few theme or brand events in the district, and therefore, not a lot of visitors are expected. Hence, the residents are the main consumers in the district.

(2) Space and planning: The connection between the blocks, the Grand Canal, and the surrounding area is good, but there is a lack of continuity in the public space corridors, and the style and features of the surrounding urban environment are coordinated. The surrounding urban space, housing, and historical blocks in the heritage area may cause conflict.

(3) Format and positioning: Block commercial environment is poor. It is difficult for people to realize the value of important industrial heritage in the area. The main flow of people in the district includes tourists and aborigines. The planning and positioning of the district integrate the usage needs of two types of people, but there are only a few places for interaction. There is a large flow of people in the district on every holiday, and there is a lack of rich and diverse leisure consumption places in the district. People's consumption choices are relatively modest in the process of recreation.

(4) Places and buildings: The district adopts the strategy of traffic diversion. The main pedestrian path is in good condition, but the internal identification of some style nodes is insufficient. The district can meet the basic needs of the motor vehicle parking, but the disorderly parking of the non-motor vehicles can seriously affect the appearance of the district. Compared with the buildings in the district, the authenticity and industrial style of the site are relatively insufficient, and the detailed design of the site in the district only relies on a small amount of industrial landscape to create the cultural nature of the site. There is a lack of space for further upgrades, such as path construction for the treatment of water interface sites.

Table 2. *Evaluation Results of the Qiaoxi Historic District.*

First level factor U1	Node 10	Node 11	Node 12
A Integration and regulation	mid	mid	mid
B Space and planning	good	good	mid
C Format and positioning	mid	mid	poor
D Architecture and site	poor	poor	poor

The following text focuses on the place and building (D) level improvement strategy.

(1) Place Traffic and Public Space Settings: Set 'One Horizontal and One Vertical' Flow Line to Series Public Nodes.

Taking into account the factors of the public vitality nodes and settlements, the new pedestrian flow line in the Qiaoxi Historic District is shown in Figure 3. The system can be summarized as a 'horizontal and vertical' streamline, a public space series, and a sword-cutting museum west square. The streamline considers the flow of the people in series with the commercial synthesis on the southern side, the bridge lane on the northern side, and the canal square on the opposite side. The streamlines penetrates the district, and creates industrial landscapes to stimulate the vitality of the street lane and increase the identification and accessibility of the industrial landscape nodes. The whole district is transformed from a single linear space to a multi-level district space. After selecting the new walking path that connects the public nodes with the poor accessibility in the district, it is also critical to consider the impact of this modification on the residential area in the district, where the planning of the tourist walking flow should be 'separate and consistent' with the original residential area. Taking the Jingshengli neighborhood of the Qiaoxi district as an example, the walking route should bypass the lanes belonging to the interior of the residential area to reduce the cross-flow and retain some privacy for the residential area. It provides places to stimulate the integration between indigenous people and tourists. For example, in the buffer area of the walking streamline and the auspicious temple settlement, the residents can sell homemade snacks, and provide an interactive platform for the tourists and indigenous people.

Figure 3. *New pedestrian flow line in the Qiaoxi Historic District.*

As mentioned previously, the unorganized parking of the non-motor vehicle affects the appearance of the district. Taking into consideration the walking pathway within the district, it is advisable to plan the non-motor vehicle parking

space uniformly to the western side of the district, ensuring the vehicles are parked in an organized way. Afterwards, it is necessary to facilitate the people to enter the site directly after parking their vehicles. According to this analysis, Table 3 shows the non-motorized vehicles that are available for parking, and Figure 4 shows the exact location. Additionally, the two squares also integrate the entrance of the underground motor vehicle garage to further separate people and vehicles. The district should have a better management plan, where special individuals should be present to guide the vehicle parking, following the planning position specification, to maintain an organized appearance of the district.

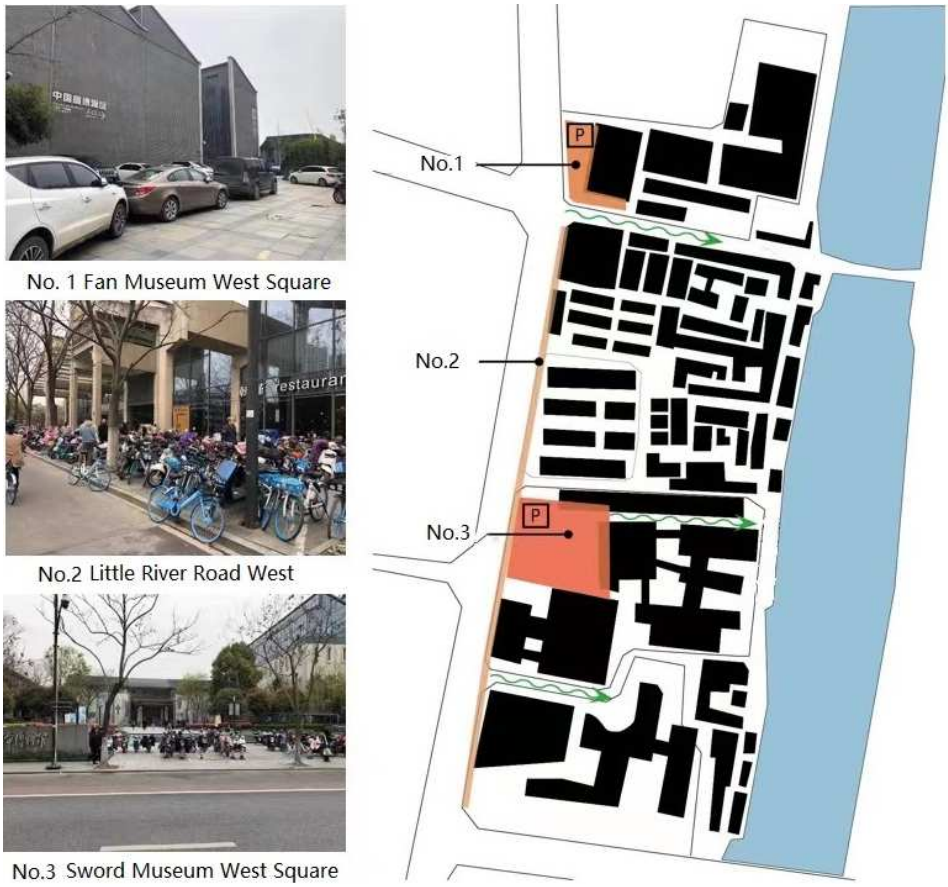

Figure 4. *Non-motor vehicle parking planning.*

Table 3. *Suggestions for parking location planning of non-motor vehicles.*

Position	Current situation	Suggested planning density
Fan Museum West Square	Motor vehicle parking, but any space planning must be non-motor vehicle parking.	Moderate planning
Westside of the district	The current parking density is high, but there is no reasonable parking location planning.	Little planning
Sword Cutting Museum West Square	The opener is less crowded, and there is no availability of parking space.	Significant planning

(2) Waterfront Relationship for the Buildings

The facade of the Fan Museum in the historical district of Qiaoxi should be reformed with the introduction of mixed formats to enhance the interaction with the waterfront landscape resources and tourists. When reconstructing the facade of the building, it is important to first assess whether the renewal action will have an impact on the building structure itself. As shown in Figure 5, the scissors and swords museum is a frame structure. Therefore, we can consider opening the facade skin to increase the permeability of the internal and external sights, so that the eastern building is better linked to the people and the waterfront environment.

In general, the problems of the Qiaoxi district are mostly concentrated in the exhibition area on the northern and southern sides of the district. Table 4 and Figure 6 show the proposed and improved strategies for the main problems.

Figure 5. *Frame structure workshop of the Umbrella museum.*

Table 4. *Problems and improvement strategies of Qiaoxi District.*

No.	Questions	Improvement strategy
1	Lack of prominent industrial value	Path: a horizontal and vertical path to guide tourists to visit and understand the industrial heritage; considerations for minimizing the interference with the residential areas in the district include integration and regulation. Landmark and node: by placing an industrial landscape, embedding the industrial materials to create a public space or a pavilion side square, and emphasizing the industrial elements.
2	Inadequate integration of industrial heritage and population	Inside the pavilion, mixed formats, commercial leisure, and other formats attract the tourists to enter and experience the internal environment. Field: Indoor and outdoor, the equipment and processes are displayed to reproduce the scenes of the cotton spinning and industrial production, and guide tourists to participate in them interactively.
3	Parking chaos has an impact on the streetscape	Mainly to regulate the non-motor vehicle parking points. The non-motor vehicles concentrated parked in the northern and southern pavilion areas near the lateral river road.
4	Open architecture and lack of waterfront relationship	The factory building on the waterside side of the Southern District Exhibition Hall is openly reformed with the adjustment of the industrial form to enhance the interaction with the crowd.
5	Lack of Waterfront Relationship	An extended hydrophilic platform is set at the waterfront square in the southern district, and it is also set at the water route junction of the Qiaoxi district.

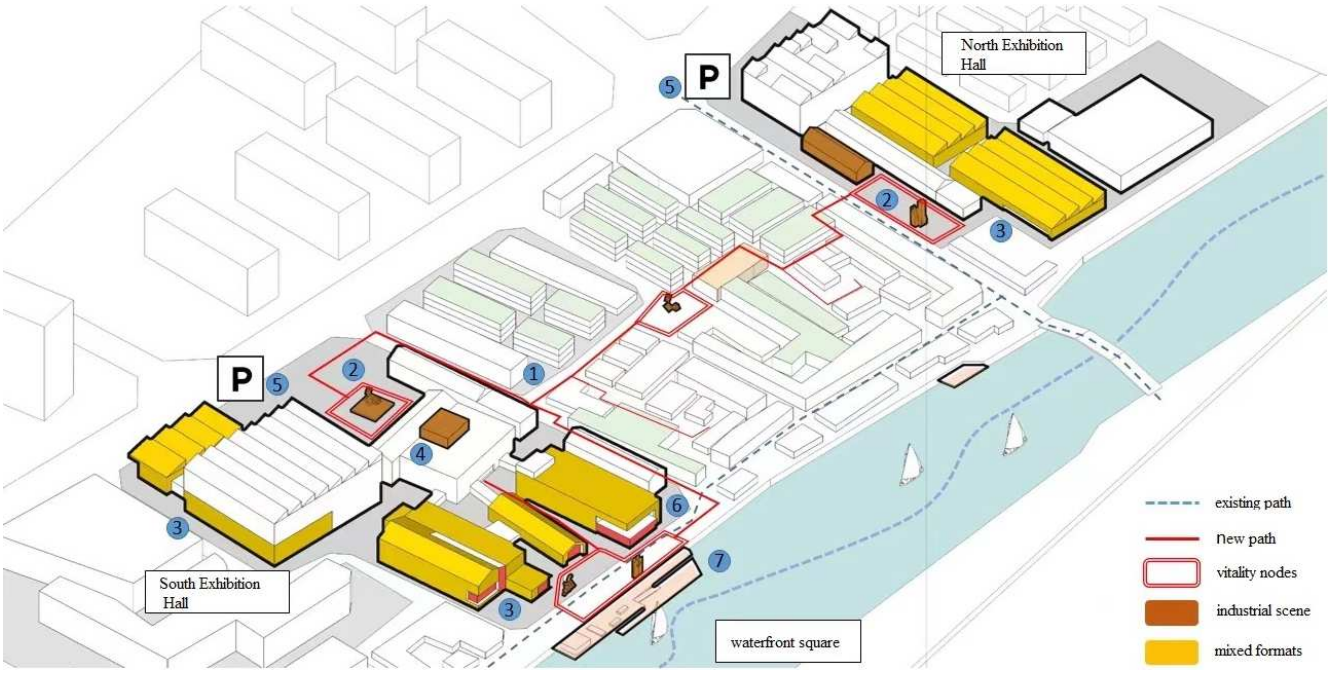

Figure 6. *Improvement Strategy of Qiaoxi District.*

5. Conclusion

An evaluation system for the urban renewal of Hangzhou Canal Qiaoxi Historic District including four first-level evaluation factors and twenty second-level evaluation factors is introduced in this paper, and an evaluation model for Qiaoxi Historic District is established using Fuzzy Analytic Hierarchy Process. So the evaluation of the urban renewal of the Qiaoxi Historic District can be conducted through a questionnaire survey from the professional and non-professional groups. According to the evaluation results, in view of the problems existing in the exhibition hall area on the north and south sides of Qiaoxi Historic District, such as the prominent industrial value, the integration of industrial heritage and population, the openness of buildings, and the relationship between waterfront, which have an impact on the style and features of the district, some specific improvement measures based on the format and positioning, architecture and place are put forward and the improvement strategies to the problem of insufficient industrial style and features of the district are suggested in this paper.

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