# A Comprehensive Evaluation of User Satisfaction with Industrial Heritage Reuse and the Optimization Strategies: Taking Zhonglian U Valley 2.5 Creative Industrial Park as an Example

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**Abstract:** The industrial heritage creative industrial park in Qingdao, which has been renovated and put to use, was selected as the research subject. Based on the data collected via the questionnaire survey and fuzzy comprehensive evaluation, the hierarchical analysis method was used to calculate the weights of indicators at each level and construct a comprehensive satisfaction evaluation model, aiming to ensure a comprehensive satisfaction evaluation and analysis of the use effect of industrial heritage following renovation and utilization. Based on the evaluation results, the existing problems in the renovation and reuse of industrial heritage in Qingdao were analyzed, and subsequently corresponding optimization strategies were proposed.

**Keywords:** AHP; Industrial heritage; Reuse; Renovation; Satisfaction evaluation; Optimization strategy

## 1. Research subject

Zhonglian U Valley 2.5 Industrial Park (thereafter referred to as "2.5 Industrial Park") in Qingdao City, Shandong Province, is located in Taiping Mountain Scenic Area, adjacent to Zelim Mountain Park, in the center of the city. It is divided into two areas, north and south, by the humpback road with a large drop. Formerly known as Qingdao Picture Tube Factory (built in 1960), it was renovated in 2008 and is now listed as an industrial heritage protection site in Qingdao. The entire park is characterized by cultural and creative industries, conforming to the 2.5 industry clustering.

## 2. Designing a comprehensive satisfaction evaluation system
### 2.1. Methodology

The questionnaire was designed, and the sample size was determined by reviewing literature, field research, and sample interviews. In order to ensure a scientific study, analytic hierarchy process (AHP) was used to establish a satisfaction evaluation model, and questionnaires were used to score and evaluate the two industrial parks. A combined method using questionnaire survey and free interview was used so as to prevent personal subjective factors from influencing the results and ensure that the questionnaire results are scientific. The interviewees included various users and investors of the industrial parks (park artists, staff, managers, and visitors), professionals from universities and design units, as well as residents in the vicinity

of the parks. The questionnaires were distributed in the two industrial parks from July 10, 2021, to July 20, 2021. The questionnaires were evaluated by means of structured questions, using a 5-point Likert scale. The semantic scale was used to classify five different levels: "Very satisfied," "Satisfied," "Generally satisfied," "Dissatisfied," and "Very dissatisfied." The semantic values of 1–5 represent the evaluation scores from good to poor. A total of 100 questionnaires were distributed to the industrial parks, of which all 100 questionnaires were valid, thus matching the sample size [1-3].

## 2.2. Evaluation indexes

An industrial heritage creative industrial park satisfaction evaluation hierarchical structure model was constructed. Based on field research, questionnaire survey, and other methods, the suggestions of experts and scholars as well as previous research results were integrated; five major indicators, B1–B5, which are all closely related to the public and easily understood by the public, were carefully selected. Several influencing factors were considered, and multiple program layers were established under the five major indicators, with a total of 29 program layers: B1, C11–C15; B2, C21–C25; B3, C31–C35; B4, C41–C47; and B5, C51–C57.

## 2.3. Evaluation index weights

In determining the evaluation index weights, expert judgment, AHP, and fuzzy comprehensive evaluation were used. The judgment matrix of the five criterion layers (B1–B5) relative to the target layer A was constructed; the weight value K of each criterion layer relative to the target layer was calculated (**Figure 1**) and tested for consistency. In the same way, five judgment matrices of each scheme layer (C11–C57) relative to the criterion layer were constructed; the weight values of each scheme layer indicator relative to the criterion layer (K1–K5) were calculated, and their consistency tests were conducted separately. When the consistency ratio (CR) is less than 0.1, the judgment matrix holds. The CR value of each judgment matrix is less than 0.1 as shown in **Table 1**, indicating that the total ranking results of each layer have satisfactory consistency. The weights of indicators in each layer were combined to obtain the weights of indicators in each program layer relative to target layer A, as in **Table 2**.
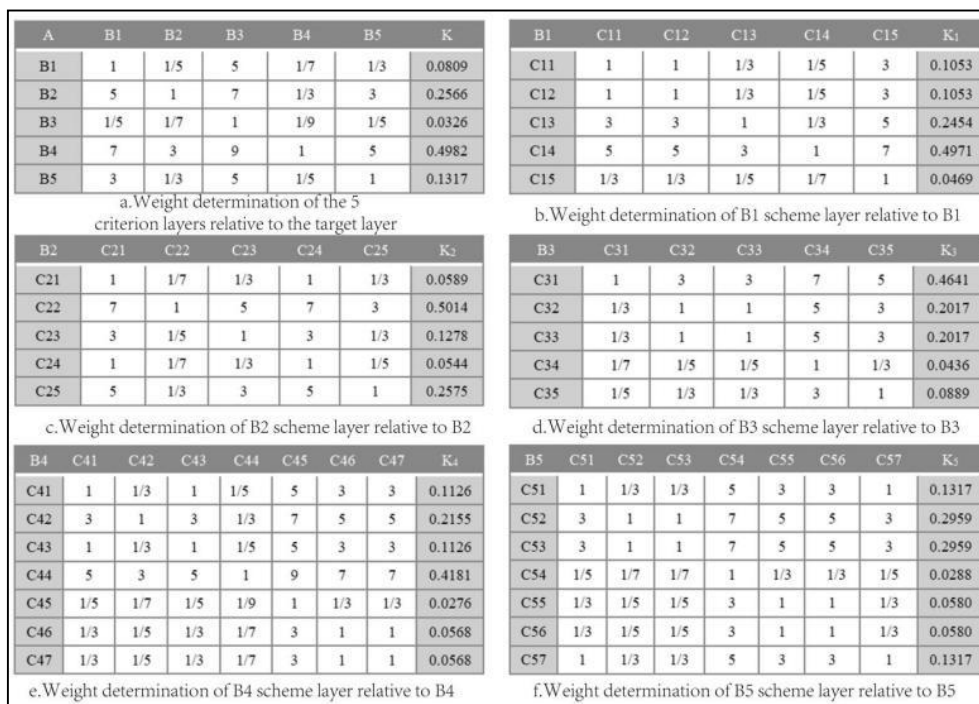
| A | B1 | B2 | B3 | B4 | B5 | K |
| --- | --- | --- | --- | --- | --- | --- |
| B1 | 1 | 1/5 | 5 | 1/7 | 1/3 | 0.0809 |
| B2 | 5 | 1 | 7 | 1/3 | 3 | 0.2566 |
| B3 | 1/5 | 1/7 | 1 | 1/9 | 1/5 | 0.0326 |
| B4 | 7 | 3 | 9 | 1 | 5 | 0.4982 |
| B5 | 3 | 1/3 | 5 | 1/5 | 1 | 0.1317 |

a. Weight determination of the 5 criterion layers relative to the target layer

| B1 | C11 | C12 | C13 | C14 | C15 | K₁ |
| --- | --- | --- | --- | --- | --- | --- |
| C11 | 1 | 1 | 1/3 | 1/5 | 3 | 0.1053 |
| C12 | 1 | 1 | 1/3 | 1/5 | 3 | 0.1053 |
| C13 | 3 | 3 | 1 | 1/3 | 5 | 0.2454 |
| C14 | 5 | 5 | 3 | 1 | 7 | 0.4971 |
| C15 | 1/3 | 1/3 | 1/5 | 1/7 | 1 | 0.0469 |

b. Weight determination of B1 scheme layer relative to B1

| B2 | C21 | C22 | C23 | C24 | C25 | K₂ |
| --- | --- | --- | --- | --- | --- | --- |
| C21 | 1 | 1/7 | 1/3 | 1 | 1/3 | 0.0589 |
| C22 | 7 | 1 | 5 | 7 | 3 | 0.5014 |
| C23 | 3 | 1/5 | 1 | 3 | 1/3 | 0.1278 |
| C24 | 1 | 1/7 | 1/3 | 1 | 1/5 | 0.0544 |
| C25 | 5 | 1/3 | 3 | 5 | 1 | 0.2575 |

c. Weight determination of B2 scheme layer relative to B2

| B3 | C31 | C32 | C33 | C34 | C35 | K₃ |
| --- | --- | --- | --- | --- | --- | --- |
| C31 | 1 | 3 | 3 | 7 | 5 | 0.4641 |
| C32 | 1/3 | 1 | 1 | 5 | 3 | 0.2017 |
| C33 | 1/3 | 1 | 1 | 5 | 3 | 0.2017 |
| C34 | 1/7 | 1/5 | 1/5 | 1 | 1/3 | 0.0436 |
| C35 | 1/5 | 1/3 | 1/3 | 3 | 1 | 0.0889 |

d. Weight determination of B3 scheme layer relative to B3

| B4 | C41 | C42 | C43 | C44 | C45 | C46 | C47 | K₄ |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| C41 | 1 | 1/3 | 1 | 1/5 | 5 | 3 | 3 | 0.1126 |
| C42 | 3 | 1 | 3 | 1/3 | 7 | 5 | 5 | 0.2155 |
| C43 | 1 | 1/3 | 1 | 1/5 | 5 | 3 | 3 | 0.1126 |
| C44 | 5 | 3 | 5 | 1 | 9 | 7 | 7 | 0.4181 |
| C45 | 1/5 | 1/7 | 1/5 | 1/9 | 1 | 1/3 | 1/3 | 0.0276 |
| C46 | 1/3 | 1/5 | 1/3 | 1/7 | 3 | 1 | 1 | 0.0568 |
| C47 | 1/3 | 1/5 | 1/3 | 1/7 | 3 | 1 | 1 | 0.0568 |

e. Weight determination of B4 scheme layer relative to B4

| B5 | C51 | C52 | C53 | C54 | C55 | C56 | C57 | K₅ |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| C51 | 1 | 1/3 | 1/3 | 5 | 3 | 3 | 1 | 0.1317 |
| C52 | 3 | 1 | 1 | 7 | 5 | 5 | 3 | 0.2959 |
| C53 | 3 | 1 | 1 | 7 | 5 | 5 | 3 | 0.2959 |
| C54 | 1/5 | 1/7 | 1/7 | 1 | 1/3 | 1/3 | 1/5 | 0.0288 |
| C55 | 1/3 | 1/5 | 1/5 | 3 | 1 | 1 | 1/3 | 0.0580 |
| C56 | 1/3 | 1/5 | 1/5 | 3 | 1 | 1 | 1/3 | 0.0580 |
| C57 | 1 | 1/3 | 1/3 | 5 | 3 | 3 | 1 | 0.1317 |

f. Weight determination of B5 scheme layer relative to B5

**Figure 1.** Determination of the weight of each indicator

**Table 1.** CR for each judgment matrix

| CR | CR$_1$ | CR$_2$ | CR$_3$ | CR$_4$ | CR$_5$ |
|---|---|---|---|---|---|
| 0.0852 | 0.0284 | 0.0581 | 0.0286 | 0.0387 | 0.0225 |

**Table 2.** Comprehensive evaluation index system and weights

| Target layer | Guideline layer | | Program layer | |
|---|---|---|---|---|
| | **Name** | **Weights** | **Name** | **Weights** |
| Comprehensive satisfaction evaluation model A of the renovated industrial heritage creative industrial park | B1 Road traffic | 0.0809 | C11 Traffic conditions around the park | 0.0085 |
| | | | C12 Convenience of access to the park by car | 0.0085 |
| | | | C13 Traffic condition inside the park | 0.0199 |
| | | | C14 Convenience of parking in the park | 0.0402 |
| | | | C15 Comfortable pavement in the park | 0.0038 |
| | B2 External spatial environment and perception | 0.2566 | C21 Whether there are noise sources and pollution sources around the park | 0.0150 |
| | | | C22 Overall style and industrial atmosphere of the park | 0.1289 |
| | | | C23 Attractiveness of the park environment | 0.0326 |
| | | | C24 Completeness of the signage system in the park | 0.0140 |
| | | | C25 Adequacy of outdoor public activity space | 0.0661 |
| | B3 Green environment | 0.0326 | C31 Degree of preservation of the industrial landscape of the park's historical heritage | 0.0151 |
| | | | C32 Attractiveness of the park's landscape artifacts | 0.0066 |
| | | | C33 Richness of landscape artifacts in the park | 0.0066 |
| | | | C34 Degree of greening in the park | 0.0014 |
| | | | C35 Utilization of green technology | 0.0029 |
| | B4 Perception after building renovation | 0.4982 | C41 Whether the functional zoning and flow lines of the park are reasonable | 0.0561 |
| | | | C42 Degree of reuse of existing industrial buildings and materials | 0.1142 |
| | | | C43 Degree of coordination between the addition and renovation of buildings and the surrounding area | 0.0561 |
| | | | C44 Recognition of building renovation methods | 0.2083 |
| | | | C45 Satisfaction with building color | 0.0069 |
| | | | C46 Satisfaction with indoor lighting and ventilation | 0.0283 |
| | | | C47 Reasonable length to width to height ratio of interior room | 0.0283 |
| | B5 Supporting facilities | 0.1317 | C51 Number and comfort of public leisure facilities | 0.0173 |
| | | | C52 Number and convenience of public restrooms | 0.0390 |
| | | | C53 Reasonability of staircase or elevator settings | 0.0390 |
| | | | C54 Brightness and effect of night lighting | 0.0038 |
| | | | C55 Completeness of barrier-free facilities | 0.0076 |
| | | | C56 Whether the number and location of garbage cans are reasonable | 0.0076 |
| | | | C57 Sufficiency of stores and cultural and sports facilities | 0.0173 |

## 3. Results and analysis

### 3.1. Evaluation results

In the satisfaction evaluation model, each single index can only reflect a single situation of the park construction; hence, a comprehensive evaluation is needed to reflect the overall situation of the park. Using fuzzy comprehensive evaluation, the function expression formula is as follows:

$$Q = \sum_{i=1}^{m} \sum_{j=1}^{n} q_{ij} K_{ij}$$

where $Q$ is the total satisfaction evaluation score following industrial heritage renovation and utilization; $q_{ij}$ is the index score of the program level; $K_{ij}$ is the weight of the corresponding program level, and $m$ and $n$ represent the number of indicators of the criterion and program level, respectively [4-6]. According to the above formula and the scoring statistics obtained from the questionnaire survey, the comprehensive score of the two industrial parks was obtained. With a score of 5 out of 5, the overall score of the 2.5 industrial park was 3.72, with reference to the satisfaction evaluation criteria of industrial heritage following renovation and utilization (**Table 3**) [7]; the 2.5 Industrial Park was categorized as "Better" and "Satisfied." This indicates that the respondents were satisfied with the renovation of the 2.5 Industrial Park.

**Table 3.** Satisfaction rating criteria for industrial heritage reuse

| Scoring range | [< 1.5] | [1.6–2.5] | [2.6–3.5] | [3.6–4.5] | [> 4.5] |
|---|---|---|---|---|---|
| Judgment result | Very Poor | Poor | General | Better | Good |
| Satisfactory rating | Very dissatisfied | Dissatisfied | Generally satisfied | Satisfied | Very satisfied |

### 3.2. Satisfaction analysis

The score of each criterion layer of the industrial park is shown in **Figure 2**, and the specific performance of each criterion layer was analyzed.
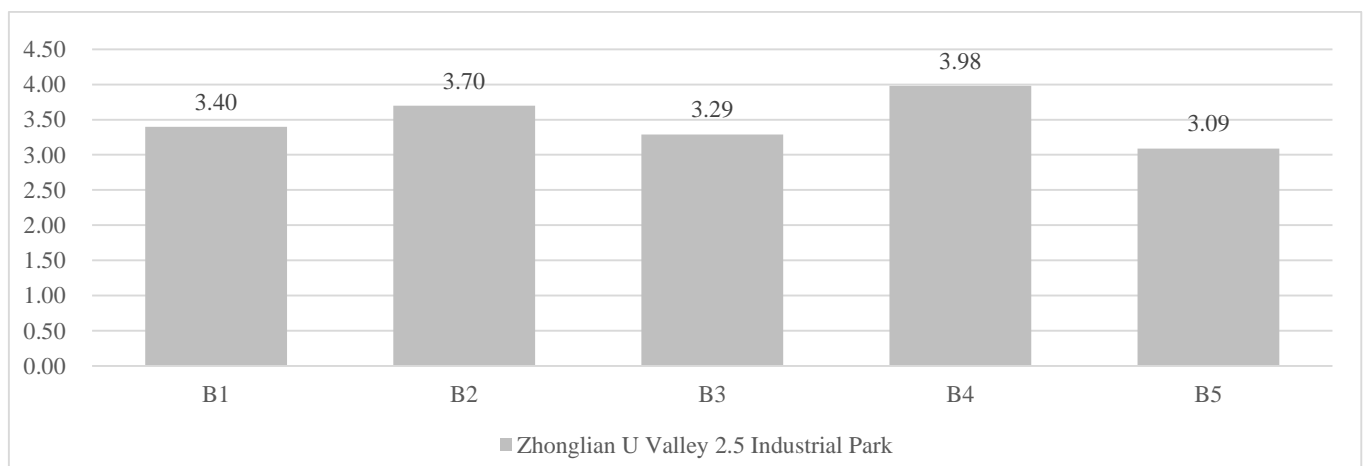


**Figure 2.** Score of each criterion layer of the two industrial parks

### 3.2.1. Road traffic guideline layer

In the road traffic guideline layer, the satisfaction rating of the 2.5 Industrial Park (3.40 points) was "Generally satisfied." The satisfaction rating of C14 (Convenience of parking in the park) (3.50 points) was "Generally satisfied," while the satisfaction rating of C15 (Comfortable pavement in the park) (2.45 points) fell under "Dissatisfied." The reason for this is that there are uneven stones over some of the ground

pavements, the gap between each stone is large, and they vary in size. Additionally, some of the ground surfaces are wasted, in which old stone slabs have been used to pave the ground. This enhances the industrial atmosphere of the park but reduces the comfort of the pavement. For children and women who wear high heels to work, it is also a safety hazard, thus causing dissatisfaction among some users.

### 3.2.2. External spatial environment and perception guideline layer

In the external spatial environment and perception criterion layer, the satisfaction rating of the 2.5 industrial park was "Satisfied" (3.70 points). The 2.5 industrial park's satisfaction ratings in the four scheme layers of C21 (4.60 points), C22 (3.72 points), C23 (3.61 points), and C24 (3.81 points) were all categorized under "Very satisfied." The satisfaction rating of C25 (3.46 points) was "Generally satisfied." This is similar to that in the field research. The 2.5 Industrial Park has a strong industrial atmosphere, with strong industrial facades, external staircases, and large smoke pipes that reflect a strong visual impact, a green environment, and more space for outdoor activities to meet the needs of users.

### 3.2.3. Green environment guideline layer

In the green environment guideline layer, the satisfaction rating of the 2.5 Industrial Park was "Generally satisfied" (3.29 points). The 2.5 Industrial Park had a satisfaction rating of "Generally satisfied" (3.29 points) in C31 (Degree of preservation of the industrial landscape of the park's historical heritage) (3.41 points), C32 (Attractiveness of the park's landscape artifacts) (3.50 points), C33 (Richness of landscape artifacts in the park) (2.90 points). In terms of C34 (Degree of greening in the park) (4.60 points) program layer performance, the satisfaction rating was "Very satisfied." Field research has confirmed that this is the case. The 2.5 Industrial Park has preserved large smoke pipes and some industrial process instruments in the renovation, set up characteristic landscape vignettes at different leisure sites, and made full use of the nooks and crannies of the park to build the "U Valley Garden," which provided users with a "back garden" for leisure walks. The "U Valley Garden" is popular among users. However, they are "Dissatisfied" with the 2.5 Industrial Park in relation to its use of green technology in C35. Although it is believed that the cost of eco-transformation is so high that it is not considered by the developers, the interview revealed that the respondents are not concerned about whether the park utilizes green technology in view of the little direct impact on users compared to other solution layers.

### 3.2.4. Perception after building renovation guideline layer

The 2.5 Industrial Park was categorized under "Satisfied" (3.98 points) in the post-renovation perception criteria layer. The 2.5 industrial park was categorized under "Very satisfied" in C41 (3.62 points), C42 (3.72 points), C44 (4.32 points), C45 (3.68 points), and C47 (3.76 points). The satisfaction rating of C41 (3.62 points), C42 (3.72 points), C44 (4.32 points), C45 (3.68 points), and C47 (3.76 points) was "Satisfied," whereas that of C46 (4.65 points) and C43 (3.45 points) was "Very satisfied" and "Generally satisfied," respectively. The 2.5 Industrial Park was formerly a picture tube factory, which had been transformed into an industrial park through addition, alteration, and demolition, preserving valuable factory buildings, large smoke pipes, some micro industrial elements of the original factory, and old trees around the factory area. The landscape steps at the terrace break the spatial fault brought by the height difference, and several terraces in the park are connected as a whole, thus weakening the sense of height difference and making users more comfortable and at ease; having a uniform architecture with lively red, white, and gray tones, the overall industrial atmosphere of the park is strong.

### 3.2.5. Supporting facilities guideline layer

C53 (Reasonability of staircase or elevator settings) (2.60 points), C54 (Brightness and effect of night

lighting) (3.50 points), C55 (Completeness of barrier-free facilities) (2.85 points), C57 (Sufficiency of stores and cultural and sports facilities) (3.45 points) were rated as "Generally satisfied." C51 (Number and comfort of public leisure facilities) (2.45 points) was categorized under "Dissatisfied." After field research, the outdoor leisure seats in the Industrial Park gradually weathered due to the lack of coating protection, and the wooden seats were covered with leaves and dust between the gaps of the wooden boards; thus, these seats were mostly non-functional; the landscape stairs were futile due to the large slope and uneven paving. Although the external steel stairs at the Industrial Park enliven the industrial atmosphere of the park, the steel stairs were not satisfactory as they emitted a "cold" feeling, thus reducing the usage rate. Upon interviewing foreigners, we learned that the number of public restrooms in the 2.5 Industrial Park are too few, and their locations are not strategic enough, making it difficult for people to locate them.

## 4. Suggestions for the transformation of the industrial heritage creative industrial park based on user evaluation

### 4.1. Improve the infrastructure of the park and enhance the core competitiveness of the park

The park should have good infrastructures in order to improve its core competitiveness. Developers and designers should focus on the indoor lighting, barrier-free facilities, greening, parking, and leisure facilities of the park to guarantee basic user experience.

### 4.2. Take the historical background of old factory buildings as the basis and bring into play the value of architectural transformation

Old factory buildings are rooted in the unique historical period and regional culture of urban development and people's needs. They have witnessed the growth of cities and carried the living memories and emotions of a generation of people. Renovating and reusing them have naturally become the focus of the government and citizens. Therefore, the inherent value of old factory buildings should be fully utilized in the renovation, so that the existing buildings and materials can be retained to the greatest extent, and the emotional attachment of the citizens can be safeguarded.

### 4.3. In-depth excavation of industrial park characteristics, precise functional positioning, and service objects

In view of the different characteristics of various industrial heritage creative industrial parks and their suitability to local conditions, the location of the industrial heritage, the scale of the factory, the level of protection, the characteristics of the building, and the degree of damage to the building all have a great influence on the renovated industrial park. For industrial heritage creative industrial parks with high heritage value and that are close to the city center, the industrial tourism development mode, which focuses on serving citizens and foreign visitors, may be considered. For instance, Textile Valley has become a travel base for many tourists following its designation as the second batch in the national industrial heritage list. For industrial heritage creative industrial parks with more recent buildings and that are far from the city center, a mixed mode of residence, office, exhibition, and leisure may be considered, or a city park open to the public can be established to serve the surrounding residents [8,9].

### 4.4. Improve public participation and create a vibrant open park

Compounded functions should be attached to create an open and vibrant park. Urban industrial heritage is a common and valuable treasure for people as it witnesses the development of the city and carries people's memories. It should not be confined to a specific object of use for a certain unit, a certain enterprise, or a certain group of people; instead, it should be a shared place for people to recall history and reminisce the past. Although the overall rating of cross-border e-commerce is high, research has revealed that cross-

border e-commerce is rarely open to the public, and it has become a workplace for enterprises stationed in the park. We strongly disagree with this practice. Industrial parks with industrial heritage value should be open to create compounded functions to attract different groups of people in the city, enhance the park's vitality, and showcase the city's industrial history.

### 4.5. Focus on ecological and cultural media to prevent excessive commercialization

According to the survey, the industrial park is slightly lacking in green ecology and cultural atmosphere, and its commercialization is so advance that it would also face the embarrassment of uniformity. In order to obtain more profit and maximize the investment scale of the park, some developers encroach on its green ecology and cultural space. This reflects the park's unreasonable pre-planning. In the future planning of industrial parks under the industrial heritage transformation category, emphasis should be on the ecology and cultural space, in which their commercial nature should be appropriately diluted to create an "ecology first" and cultural creative park [10].

### 5. Conclusion and expectation

In the 2.5 Industrial Park survey, questionnaire survey and AHP were used for perceptual evaluation. From the perspective of users, both the advantages and disadvantages of industrial heritage renovation and reuse can be clearly identified. The purpose of optimizing the current situation of industrial heritage renovation and creative industrial parks is to ensure a reasonable reuse of industrial heritage, explore the needs of different users, innovate designs based on humanization, and actualize these sites as real gathering places for human flow rather than mere urban functional spaces.

### Disclosure statement

The authors declare no conflict of interest.

### Author contributions

G.Y. conceived the idea of the study, and W.R. performed the experiments, analyzed the data, and wrote the paper.

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