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The Engineering Practice of Industrial Heritage Renovation and Renewal from the Perspective of Open Architecture -- A Case Study of a Machine Tool Factory

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Abstract: The CCP's 20th report points out that accelerating the construction of a new development pattern and focusing on promoting high-quality development In promoting the regional coordinated development, industrial heritage transformation, as an important part of the urban renewal movement, plays an important role in promoting regional development and activating regional space. By applying the concept of hierarchy division in the open architecture theory to the transformation and renewal of industrial heritage, the components of the old industrial plant structure and plant building can be decomposed from the level of individual buildings. This paper supplements the consideration factors of open architecture, and forms a universal research method of value evaluation of industrial heritage from the perspective of open architecture, including the selection of value evaluation indicators, the construction of system, the distribution of index weights and the evaluation results. Exploring new methods for industrial heritage renewal design using a certain machine tool factory as an example.

Keywords: Open Architecture, Industrial Heritage, Hierarchy, Value Evaluation, Renovation and Renewal

1. Introduction

From the Athens Charter in 1993 to the Nizhni Tagil Charter in 2003, the policy of international industrial heritage protection has been maturing. The establishment of industrial heritage conservation groups and recognized conservation organizations has gradually become an issue of global concern [1].

Professor Liu Boying from Tsinghua University published Research on the Protection and Reuse of Industrial Heritage Resources in Shougang Industrial Park in 2006 [2], Overview on the Protection and Development of Industrial Architectural Heritage in 2012 [3], and the Confusion and Reunderstanding of Industrial Heritage in the papers of the 7th Academic Seminar on Industrial Architectural Heritage in 2016 [4]. The paper elaborated on the confusion in the cognition of China's industrial heritage since the Wuxi Proposal, and made a more macroscopic discussion on industrial heritage from various aspects. In 2023, it published Review and Prospect of the Conservation and Utilization of old Industrial Buildings in Beijing under the Background of Industrial Land Renewal [5], and in 2022, it published a Preliminary Study on the Core Value of New China's Industrial Heritage [6]. Meng Fanlei, associate professor of Beijing University of Civil Engineering and Architecture, published articles such as Research on the History of Modern Beijing Industrial Construction and the Value of Industrial Building Heritage [7].

The core of open architecture theory is hierarchical division. According to the length of building life and each part according to the control and control hierarchy structure, the building is divided into support and filling. The city can be divided into three levels: urban texture level, building monomer level and separable level [8]. This paper mainly studies the construction of block level and building monomer level, that is, the block structure level corresponds to the old

industrial plant, and the building monomer level corresponds to the old industrial monomer plant, and divides the supporting body and the filling body to provide the basis for the renewal and transformation of industrial heritage. A set of evaluation standard system of industrial heritage value based on the concept of open architecture is formed, and quantitative methods such as AHP (Analytic Hierarchy Process) are adopted to obtain comprehensive evaluation results. The support and filling bodies of the block structure level (old industrial plant area) and building monomer level (old industrial building) should be re-divided and retained or removed to increase the flexibility of the building structure and spatial layout. It is applied to the actual case of Jinan No. 1 Machine Tool Factory to verify the feasibility of the research method on the renovation and renewal of old industrial plants from the perspective of open architecture.

2. Establishment of Value Evaluation System of Industrial Heritage

2.1. The Basic Value Constitution of Industrial Heritage

It is reasonable to apply the value recognition and research system of cultural heritage to the value evaluation of industrial heritage. The current authoritative value system of China's cultural heritage is the Law of the People's Republic of China on Cultural Heritage (2013, hereinafter referred to as the Cultural Heritage Law), which indicates that the basic value of Chinese cultural heritage includes historical, artistic and scientific values. The 2015 edition of the "Guidelines for the Protection of Cultural Relics and Monuments in China" (hereinafter referred to as the "Guidelines") emphasizes the social extension of cultural heritage - social value and cultural value. Domestic scholars on industrial heritage have concluded that the basic composition of industrial heritage value should include historical value, cultural value, social value, scientific value and artistic value [9].

Based on the economic "cultural capital" proposed by Australian economist David Throby, Professor Xu Subin proposed that the inherent value of industrial heritage includes four kinds of capital in economics: material, human, natural and cultural [10].

2.2. Domestic Industrial Heritage Value Evaluation Standard System and Selection

Based on the Law of Cultural Relics, Guidelines, the author selects the pre-selection standard framework of the value evaluation system of industrial heritage proposed by Professor Xu Subin [11]. The values of history, science and technology in the first-level standards of the framework are consistent with the four basic values in the Guidelines, and eight value impact factors are added, such as authenticity and representativeness.

2.3. Factors to Consider in the Value Evaluation of Industrial Heritage from the Perspective of Open Architecture

The value evaluation system of industrial heritage adds 4 factors of open building consideration, which is the first-level standard and enriches the content of value evaluation from multiple dimensions.

(1) Time dimension value: First, evaluate its use time period. The second is to evaluate whether it has long-term self-renewal and support ability in terms of spatial change. With the change of time and needs, the replacement and re-division of the internal space function of industrial buildings; (2) The value of effective reuse of resources: the open building integrates the efficiency of resource and energy use, integrates the variable demand brought by environmental changes with the building, and the building is demolished because of the impact of functional life rather than physical life. Open architecture is to retain the supporting body, discard or replace the filling body, and replace the new functional life to realize the whole life cycle of the building [12]. (3) Variable value: the support body limits the regular space to accommodate functional changes, thereby improving the adaptability of the building. The filling body level can complete various changes within a certain limit, improving the flexibility of the building to meet the different needs of the same building space. (4) Urban style value: From the perspective of open architecture, urban style is the result of superimposed layers of city, block and building monomer.

3. Evaluation Standard System of Industrial Heritage Value from the Perspective of Open Architecture

The evaluation system of industrial building heritage value is the main framework, and AHP is used to decompose the evaluation objectives layer by layer, and classify and rank according to the attributes of the evaluation factors, thus forming the final hierarchical structure of the objectives [13]. This evaluation system divides the index system of the industrial building heritage value evaluation system into three levels: the general target level is "Industrial heritage value evaluation system from the perspective of open architecture", there are 9 criteria level (primary index) and 17 sub-criteria level (secondary index), as shown in Table 1.

Table 1. *Evaluation standard system of industrial heritage value from the perspective of open architecture.*

Overall objective	Primary index	Secondary index
Industrial heritage value evaluation system A1 from the perspective	Historical Value B1	Historical age C1
		Relevance and importance to historical figures, historical events, important groups or institutions C2
		Evidence value C3

Overall objective	Primary index	Secondary index
of open architecture		Spiritual and cultural values C4
	Social and cultural value B2	Social and cultural values C5
		Role played by industrial production activities C6
		Emotional identification of enterprise spirit and culture C7
	Artistic value B3	Industrial production and production of memories of belonging C8
		Visual aesthetic quality of industrial structures and industrial landscapes C9
		Relevance and importance to a certain style, designer, etc. C10
	Technology value B4	The advanced nature and importance of industrial equipment, production process and production mode C11
		The advanced nature and importance of building structure, materials, construction technology, planning and design, etc
		Relevance and importance to famous technicians, engineers, architects, etc. C13
	Authenticity B5	Reconstruction and repair status C14
		Save status C15
	Integrity and group value B6	The integrity of regional industrial chain and industrial cluster C16
		The integrity of the production line (machinery, equipment and structures), the plant area C17
	Representative B7	Higher value and importance when compared to similar types of heritage C18
		It can cover different periods, different types, different regions, and various types of balance C19
	Scarcity B8	The scarcity of building resources is similar to the number and scarcity of industrial building resources C20
		Scarcity of landscape resources, scarcity of industrial landscape resources in a certain region C21

In the evaluation standard system established in this paper, the above four factors considered in the evaluation of open building value and the selected evaluation standard system of industrial heritage value are not co-located in the same rating system framework, but exist as the subsidiary value evaluation system of the latter, as shown in Table 2. After the comprehensive evaluation results of the industrial heritage are obtained under the two evaluation systems, the final value comprehensive evaluation scores are added to calculate the comprehensive evaluation results of industrial heritage value from the perspective of open architecture.

Table 2. *Factors considered in the evaluation of industrial heritage value from the perspective of open architecture.*

Overall objective	Primary index	Secondary index
Factors A1 of industrial heritage value evaluation from the perspective of open architecture	Time value B1	Building and structure service life C1
		The self-changing ability of space, the existing hindrance or influence of buildings with large-span truss structure on space change C2
		Future variability of value indicators C3
	The effective reuse value of resources B2	Efficiency of resource and energy use C4
		Industrial building structures, industrial equipment and other effective reuse of C5
	Adaptability and flexibility value B3	Adaptability to adopt or replace new functions C6
		Flexibility in space layout and renovation C7
	City style value B4	Maintain the city style ability of block level and building monomer level superimposed C8
		Uniqueness, scarcity C9

4. Evaluation Method of Industrial Heritage Value from the Perspective of Open Architecture

In this paper, a variety of evaluation methods are comprehensively applied according to the specific situation in the evaluation research: AHP method is mainly used in the construction of industrial heritage value evaluation system from the perspective of open architecture. To construct evaluation index hierarchy and assign index weights [14]; When it is impossible to analyze the evaluation index with a unified dimension, the comprehensive scoring method is used to grade and evaluate, and finally the comprehensive score of the evaluation object is obtained.

4.1. The Analytic Hierarchy Process Determines the Hierarchical Structure Model of the Value Evaluation Index System

Its structural relationship can be divided into general objective layer, criterion layer, index layer and factor layer [9]. The selected index system of industrial heritage value evaluation and the consideration factor system of industrial heritage value evaluation from the perspective of open architecture comprise the hierarchical structure model of industrial heritage value evaluation index system from the perspective of open architecture.

4.1.1. Construct Judgment Matrix

By pair-to-pair comparison (including comparison of elements themselves) between 8 indicators in the criterion layer (primary index) and 17 indicators in the sub-criterion layer (secondary index) of the selected industrial heritage

value evaluation standard system, the judgment matrix is constructed, and the structural matrix of the influence factor system of open buildings on industrial heritage value evaluation is obtained, as shown in Table 3.

Table 3. *Construction matrix of first-level criteria index of influencing factors of industrial heritage evaluation from the perspective of open architecture.*

	historical value	Social and cultural value	artistic value	Science and technology value	Integrity and group value	typical	scarcity	facticity
historical value	1	2	3	2	2	3	2	1
Social and cultural value	1/2	1	2	1	1	1	2	1/2
artistic value	1/3	1/2	1	1/2	1/3	1/4	1/4	1/5
Science and technology value	1/2	1	2	1	1/2	1	1	1/2
Integrity and group value	1/2	1	3	2	1	1	1	1
typical	1/3	1	4	1	1	1	2	1
scarcity	1/2	1/2	4	1	1	1/2	1	1
facticity	1	2	4	2	1	1	1	1

4.1.2. Yaahp Software Assisted to Obtain the Weight Results

In this paper, AHP auxiliary software - yaahp is selected to facilitate the operation of AHP. The hierarchical structure model and judgment matrix data of the value evaluation index system are input into yaahp, and the weight calculation results are obtained at last. Thus, the judgment matrix of each level of the industrial heritage value evaluation system from the perspective of open architecture is established, and the weight calculation results of each element are obtained.

4.2. The Comprehensive Scoring Method Measures Quantification

When the evaluation index can not be analyzed with a unified dimension, especially some subjective evaluation indicators, it can be graded with comprehensive scoring method. In order to quantitatively measure the evaluation index of industrial heritage value from the perspective of open architecture established above, and judge the score of each sub-item, it is necessary to establish corresponding scoring criteria based on the actual situation of industrial heritage, and divide the basic index of industrial heritage value evaluation into five grades (1-10 points): excellent, good, average, poor and very poor. Organize experts to score each item, and provide the basis for the final data analysis and evaluation results.

5. Comprehensive Evaluation of an Actual Cases

5.1. Value Evaluation of Each Element of the Park Structure Level

According to the determined evaluation system of industrial heritage value from the perspective of open architecture, the weight of each index is set and the index scoring standard is determined, the value of each element of a specific park structure can be comprehensively evaluated.

5.1.1. Components of Old Industrial Plants (Park Structure Level)

The components of the old industrial plant can be divided into seven categories according to their functions: standard factory area, professional factory area, warehouse area, management area, public and public facilities area, living area, and road land (Figure 1).

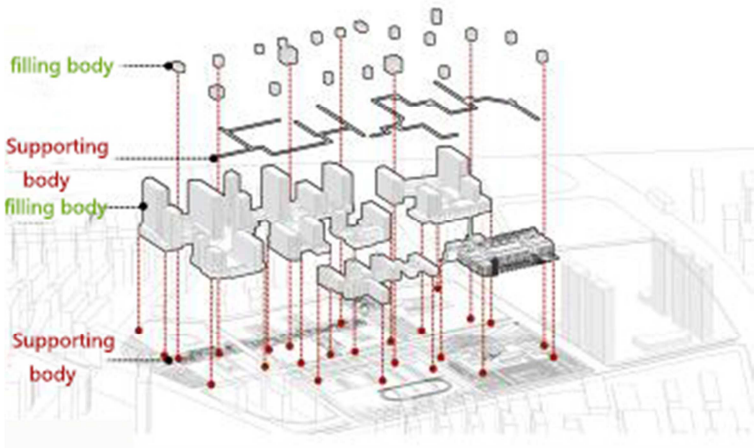

Figure 1. *Components of Jinan Machine Tool Factory.*

5.1.2. Workshop 2 Evaluation Process

In this paper, Workshop No. 2 of Jinan Machine Tool Factory No. 1, a component of the factory, was selected for evaluation. The workshop was completely preserved and was a project assisted by the Soviet Union to build China during the "First Five-Year Plan" period, which is a typical

representative of industrial heritage (Figure 2).

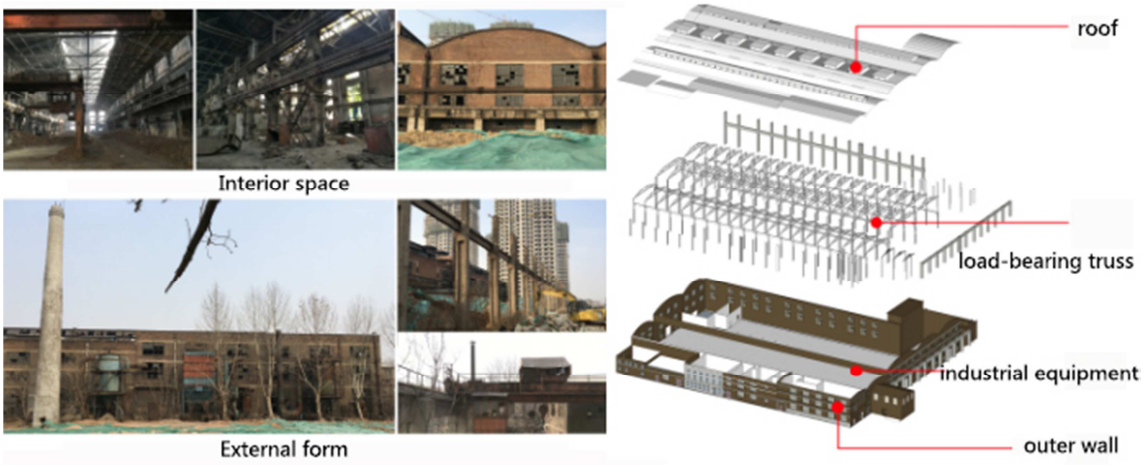

Figure 2. *No. 2 Workshop of Jinan Machine Tool Factory Decomposition of components of No. 2 workshop.*

This paper invited 10 professional and technical personnel to evaluate the value of Workshop No. 2. Table 4 (Refer to appendix) is the index rating table of one of the evaluators.

Table 4. *Evaluation index of plant value evaluation No. 2.*

Scoring sub-indicators	**Scoring Criteria and Descriptions**					
	Excellent (9-10).	**Good (7-8).**	**General (5-6).**	**Poor (3-4).**	**Very poor (0-2).**	**Plant 2 scored**
Historical Chronology C1	1840-1911	1912-1948	1949-1960	1961-1980	After 1981	9
Relevance and importance to historical figures, events, important groups or institutions C2	Important Events	More important events	General events	No incidents	No relevance	9
Physical Evidence Value C3	Higher	Very high	So so	Poor	Very poor	9
Spiritual and Cultural Values C4	Higher	Very high	So so	Poor	Very poor	7
Socio-cultural values C5	Higher	Very high	So so	Poor	Very poor	8
Role played by industrial production activities C6	Higher	Very high	So so	Poor	Very poor	9
Emotional identity of enterprise spirit and culture C7	Higher	Very high	So so	Poor	Very poor	7
A sense of belonging to industrial production and production memory C8	Higher	Very high	So so	Poor	Very poor	8
Visual Aesthetic Quality of Industrial Structures and Industrial Landscapes C9	Higher	Very high	So so	Poor	Very poor	7
Relevance and importance to a certain genre, designer, etc. C10	More important	Very important	So so	Poor	Very poor	8
The advancement and importance of industrial equipment, production technology, and production methods C11	More important	Very important	So so	Poor	Very poor	7
The advancement and importance of building structure, materials, construction technology, planning and design, etc. C12	More important	Very important	So so	Poor	Very poor	7
Relevance and importance to renowned technicians, engineers, architects, etc. C13	More important	Very important	So so	Poor	Very poor	7
Reconstruction and Restoration Status C14	Better	Very good	So so	Poor	Very poor	7
Preservation status C15	Better	Very good	So so	Poor	Very poor	7
Integrity of regional industrial chains and industrial clusters C16	Relatively complete	It's complete	So so	Poor	Very poor	7
Integrity of production lines (machinery and buildings) and plant sites C17	Relatively complete	It's complete	So so	Poor	Very poor	7
It has a higher value and importance when compared to the same type of heritage C18	More important	Very important	So so	Poor	Very poor	8
It can cover different periods, different types, different regions, and various types of equilibrium C19	Higher	Very high	So so	Poor	Very poor	7
The rarity of building resources, similar to the number and scarcity of industrial building resources now C20	Scarce	Very scarce	So so	Poor	Very poor	7
The rarity of landscape resources, the scarcity of industrial landscape resources within a certain area C21	Higher	Very high	So so	Poor	Very poor	6
The service life of the building and structure is C22	Longer	It's long	So so	Poor	Very poor	7
The ability of space to change itself, the existing obstacles or influences of large-span truss structures to space changeC23	Larger	It's huge	So so	Poor	Very poor	7
Future Variability of Value Metrics C24	Larger	It's huge	So so	Poor	Very poor	6
Resource and energy efficiency C25	Higher	Very high	So so	Poor	Very poor	7
Effective reuse of C26 for industrial building structures, industrial	Higher	Very high	So so	Poor	Very poor	7

Scoring sub-indicators	Scoring Criteria and Descriptions					
	Excellent (9-10).	Good (7-8).	General (5-6).	Poor (3-4).	Very poor (0-2).	Plant 2 scored
equipment, etc						
Adaptation C27 to incorporate or replace new features	Strong	Very strong	So so	Poor	Very poor	8
Flexibility in space layout and retrofit C28	Strong	Very strong	So so	Poor	Very poor	8
Maintain the cityscape ability C29 at the block level and the individual building levels	Strong	Very strong	So so	Poor	Very poor	7
Uniqueness, scarcity C30	Higher	Very high	So so	Poor	Very poor	6

Multiply the scores of each index by their respective weight values, and then add these values together to obtain the total score of the industrial heritage value that the evaluator considers.

$$X_{\text{workshop No.2}}=(9\times0.0167+9\times0.0862+9\times0.0533+7\times0.0226+8\times0.0201+9\times0.0264+7\times0.0226+8\times0.0226+7\times0.0287+8\times0.0143+7\times0.0235+7\times0.0235+7\times0.0471+7\times0.0835+7\times0.0835+7\times0.0835+7\times0.0431+8\times0.0652+7\times0.0652+7\times0.0543+6\times0.0543)=6.9928\approx7$$

$$X_{\text{workshop No.2}}=(7\times0.2136+7\times0.1136+6\times0.0403+7\times0.0544+7\times0.1633+8\times0.1844+8\times0.0922+7\times0.0346+6\times0.1037)=7.1331$$

Weighted average scores of multiple evaluators can be used to calculate the comprehensive evaluation results of industrial heritage value. The final comprehensive evaluation score of No. 2 plant of Jinan Machine Tool Factory can be calculated.

$$Xi_{\text{workshop No.2}}=(6.9928+7.1317+7.9769+7.0324+7.5648+6.9786+7.0534+7.9537+8.0456+7.2331)/10=7.3963$$

$$Xi_{\text{workshop No.2}}=(7.1331+7.5648+7.5438+8.0945+7.2457+7.3342+8.4746+8.0247+7.4592+8.3251)/10=7.7200$$

The final score results can basically reflect the basic situation of the value of old industrial plants, and to a certain extent, verify the applicability of the evaluation index system of industrial heritage value from the perspective of open architecture. Ratings are used as a reference (9-10 excellent, 7-8 good, 5-6 fair, 3-4 poor, 1-2 very poor). The final score of this evaluation is composed of two parts: the evaluation score of the selected industrial heritage value and the evaluation score of the factors considered in the evaluation of industrial heritage value from the perspective of open architecture, that is, the score of No. 2 workshop (7.39 + 7.72)/2=, which can give the comprehensive value evaluation of No. 2 workshop a good grade. (When the scores of the two parts are inconsistent, the weighted average can be obtained to obtain the final result.) In this paper, the dividing line of supporting layer level and filling layer level is set as 7 points.

5.2. Value Evaluation of Each Element of Building Monomer Level

5.2.1. Elements of Old Industrial Buildings (Building Monomer Level)

The old industrial plant consists of load-bearing components, support system, enclosure system, internal equipment and the outside of the plant. Load-bearing components include load-bearing components (transverse shelving, longitudinal connection components), including roof structure (load-bearing components: roof truss, roof beam), columns, foundations, foundation beams, ring beams, connecting beams, crane beams; External wall (load-bearing wall, load-bearing wall, frame wall); The support system includes two types: roof support and column support; The enclosure system includes external walls (ibid.), Windows (side Windows, skylights), gates, roof covers (covering components such as roof panels, purlins or tiles).

General old industrial plants also have equipment for the production and transportation of raw materials and processed products. Taking the No. 2 casting workshop of Jinan Machine Tool Factory as an example, in addition to the truss structure, columns, etc., the interior also retains the crane track, sand clearing pit, dispatch control equipment, box closing equipment, working stairs, elevated pipes, gantry crane, etc., because of its production function of machine tool castings. The facade shape and window form of the workshop, and its external preservation shelving, cinder collection furnace, chimney, transportation railway, etc. Classification diagram of components of old industrial plants.

Same as the evaluation method of Workshop No. 2 in Section 4.1.2, it is concluded that the support body of all components of Workshop No. 2 can be retained, and the filling can be retained or discarded according to the actual transformation and updating. It is concluded that the supporting body of all components of No. 2 workshop can be retained, and the filling can be retained or discarded according to the actual transformation and updating.

Total score of load-bearing trusses inside No. 2 workshop:

$X_{\text{load-bearing truss No.2}}=7.6279$

$X_{\text{load-bearing truss No.2}}=9.38$

Then the weighted average of the scores of several evaluators can calculate the comprehensive evaluation results of the industrial heritage value of load-bearing trusses.

$Xi_{\text{load-bearing}}=8.2820$

$Xi_{\text{load-bearing}}=8.6352$

According to the previous section, the load bearing truss has a score of (8.28 + 8.64) /2=8.4586). It belongs to the good grade, which can be obtained that the comprehensive value evaluation of No. 2 workshop is good grade.

5.2.2. Evaluation Result

The components of Plant 2 with more than 7 points are: Load-bearing truss 8.5, bull leg column 8.6, foundation 7.3, foundation beam (crane beam, connecting beam, ring beam) 7.3, column support 7.5, external wall 7, trusses 8.5, gantry crane 7.8, gantry crane cab 7, crane (transport) track 7.1, sand clearing pit 7.4, dust removal equipment 7.7, cinder collecting furnace 7.8, chimney 8.5, transport iron Route 8; The component elements below 7 points are: facade window 6.3, roof side skylight 6.5, gate 6.1, roof cover 6, box closing equipment 6.4, working stairs 6.1, elevated pipeline 6, furnace 6, power distribution equipment 5.8, facade shape 6.2, window form 6.5. More than 7 points of the building elements in No. 2 are retained as support bodies. In the subsequent renovation, fillers can be implanted on the basis of the support body according to the updating design needs, providing valuable design basis and hypothesis for the renovation of No. 2 workshop from the perspective of open architecture (see Figure 3).

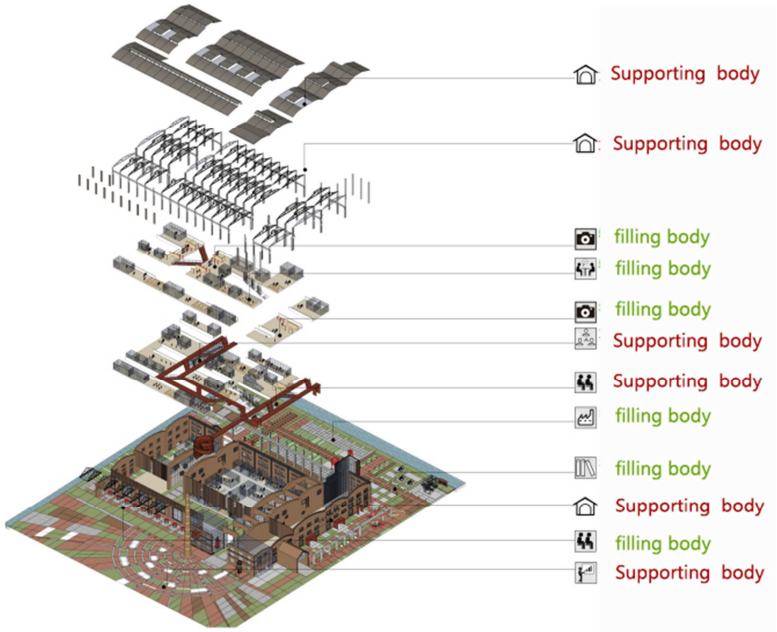

Figure 3. *The updated component elements of No. 2 plant are decomposed.*

6. Conclusion

Based on the selection of the current domestic industrial heritage value evaluation system standards and the integration of industrial heritage value evaluation considerations from the perspective of open architecture, this paper forms a set of value evaluation systems for old industrial plants and old industrial buildings that are applicable to the concept of open architecture, and adopts quantitative methods such as AHP to give comprehensive evaluation and obtain evaluation results. According to the comprehensive evaluation results, for the block structure level (old industrial factory) and building monomer level (old industrial building), the support body and filling body level are reconstructed to increase the flexibility of building structure and spatial layout.

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Conflicts of Interest

All the authors do not have any possible conflicts of interest.

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