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Research on Value Evaluation and Conservation–Reuse of Industrial Remains of the Coal Mine Machine Repair Plant Type: A Case Study of the Tianfu Coal Mine Machine Repair Plant in Chongqing

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Abstract This paper studies the architectural remains of the Tianfu Coal Mine Machine Repair Plant in Chongqing. It aims to build a value evaluation system for industrial remains of the coal mine machine repair plant type and to propose conservation and reuse strategies. The study combines international charters, Chongqing industrial heritage evaluation literature, and expert suggestions. It identifies six value indicators: history, society, science and technology, art, economy, and integrity, along with fifteen evaluation factors. The Delphi method determines weights. The analytic hierarchy process calculates indicator weights. The matter-element extension model calculates correlation degrees and classifies grades. Based on this, 18 architectural remains in the plant are evaluated. Results show that historical value has the highest weight, followed by scientific and technological value. Economic value and integrity value are in the middle. Social value and artistic value are relatively low. Sun Yueqi's office reac hes Grade V. The grinding machine workshop, power generation workshop, southeast corner factory building, Metalworking Workshops No.1 and No.2, belt lathe, and riveting and welding workshop are Grade IV. The rest are mostly Grade II or Grade III. Based on these results, the study proposes graded demolition and retention suggestions. It takes Metalworking Workshop No.2 as an example to explore a reuse design path led by "technology display + cultural and creative experience". Through the closed-loop logic of "evaluation first, decision second, design third", this study provides a scientific basis for revitalizing the Tianfu Coal Mine Machine Repair Plant. It also offers a methodological reference and practical paradigm for conserving and reusing similar coal mine industrial remains.

Keywords Industrial heritage, Value evaluation, Matter-element extension model, Conservation and reuse, Tianfu Coal Mine Machine Repair Plant

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Industrial heritage is the material and cultural legacy of industrialization. It reflects the technology, production methods, and social memory of a specific era. Since TICCIH adopted the Nizhny Tagil Charter in 2003, industrial heritage conservation and reuse have become key issues in cultural heritage[1]. In China, urbanization is shifting from incremental expansion to stock optimization. Many industrial plants and mining facilities built in the mid-to-late twentieth century now require functional replacement and spatial restructuring[2]. How to assess industrial remains scientifically and formulate reasonable conservation and reuse strategies has become a shared concern in architecture, urban planning, and cultural heritage conservation.

Chongqing is a major birthplace of modern industry in China. It has many industrial and mining remains from the Third Front Construction period and the War of Resistance[3]. The Tianfu Coal Mine Machine Repair Plant is a typical example. It is located in Tianfu Town, Beibei District, Chongqing, and has a history of nearly 90 years. After power generation and machine repair equipment from the Henan Zhongfu Coal Mine Company arrived in 1938, equipment installation and plant construction began. Its history has three stages: the Tianfu Coal Mine Machine Repair Plant of the Tianfu Mining Bureau (1938–1989), the Machinery Manufacturing Plant of the Chongqing Tianfu Mining Equipment Manufacturing General Factory (1990–2003), and partial restructuring into the Chongqing Tianjucheng Machinery Manufacturing Co., Ltd. (2004–present). The plant covers 26,000 m², with industrial buildings occupying 10,749 m². These include the metalworking workshop, mine car three-ring chain processing workshop, belt lathe, ironworking shop, riveting and welding workshop, and carriage storage workshop.

After all coal mines in Chongqing closed in 2016, most buildings of the plant became idle. Scientific value evaluation is urgently needed to support conservation and reuse decisions.

Current research on industrial heritage evaluation has produced useful results. Evaluation methods fall into three categories: qualitative, quantitative, and combined. Qualitative evaluation relies on subjective judgment and lacks objectivity and comparability. Quantitative evaluation enables multi-dimensional comparison through unified standards, but struggles with fuzziness and dynamism. The combined method integrates both advantages and is now widely used. International charters and domestic scholars often build evaluation frameworks from history, society, science and technology, art, economy, and integrity. However, research on coal mine industrial remains is still weak, especially for machine repair plants of relocated industrial and mining enterprises in southwestern China. Existing studies mainly focus on urban waterfront industrial belts or large steel and textile plants. They pay insufficient attention to coal mine machine repair plants, which combine manufacturing and mining service functions. Regional adaptability and type specificity of evaluation indicators need improvement.

This paper takes the architectural remains of the Tianfu Coal Mine Machine Repair Plant as its research object. It aims to build a value evaluation system for coal mine machine repair plant remains and propose conservation and reuse strategies. The research first identifies six value indicators (i.e., history, society, science and technology, art, economy, and integrity)

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and fifteen evaluation factors through literature review, field investigation, international charters, Chongqing industrial heritage evaluation literature, and expert suggestions. It then uses the Delphi method to determine weights, the analytic hierarchy process to calculate indicator weights, and the matter-element extension model for correlation calculation and grade classification. On this basis, it evaluates 18 architectural remains in the plant. Finally, it proposes demolition and retention suggestions and explores the reuse design of Grade IV remains through Metalworking Workshop No. 2. The study follows a closed-loop logic of "evaluation first, decision second, design third". It aims to provide a scientific basis for revitalizing the Tianfu Coal Mine Machine Repair Plant and a methodological reference for similar coal mine industrial remains.

1 Overview of the Tianfu Coal Mine Machine Repair Plant

The Tianfu Mining Bureau is the largest of Chongqing's five major mining bureaus. The Tianfu Machine Repair Plant is an important part of it. It has great influence, well-preserved architectural remains, and clear architectural boundaries. In 1943, the plant produced the first steam locomotive in the mining area. This filled the coal transport capacity gap of the Beichuan Railway. It was an important example of independent research and manufacturing by industrial and mining enterprises in the rear area during the War of Resistance. It also set a precedent for coal mining enterprises in southwestern China to manufacture locomotives. The preserved buildings were mainly built in the 1940s and 1980s. The former site of Sun Yueqi's office and the power generation workshop are rated as outstanding historical buildings of Chongqing. Large-span factory buildings, represented by the metalworking workshop, grinding machine workshop, and riveting and welding workshop, have well-preserved appearances and structures. They have high value for utilization and renovation.

2 Construction of the evaluation system for the architectural remains of the Tianfu Coal Mine Machine Repair Plant

2.1 Determination of evaluation methods

Mainstream industrial heritage evaluation methods include qualitative evaluation, quantitative evaluation, and combined evaluation[4-7]. Qualitative methods rely on subjective evaluation and lack objectivity and scientificity. Quantitative methods establish unified standards and quantify multi-dimensional value comparison. The combined method integrates the advantages of both and is widely adopted. This study uses the combined method. The Delphi method determines weights[8], the analytic hierarchy process calculates weights[9], and the matter-element extension model calculates correlation degrees to obtain the grade of architectural remains[10].

2.2 Selection of evaluation indicators and factors

Based on international charters, field investigation, Chongqing industrial heritage evaluation literature, and expert suggestions, this study proposes six value indicators for coal mine industrial remains in Chongqing: history, society, science and technology, art, economy, and integrity[11-12].

(1) B1 Historical value. Historical value is judged by two core aspects: historical background and age, and association with major historical events and well-known figures. Construction age is the basis of historical depth. Older remains carry more precious industrial imprints and serve as physical carriers for restoring regional modern industrial development. Whether remains participated in or witnessed major industrial events, and whether they are deeply associated with well-known figures, directly determine the uniqueness and scarcity of their historical narrative. This is the core criterion for judging historical status.

(2) B2 Social value. Social value is judged from two dimensions: contribution to regional development and empowerment of local spiritual culture. As products of regional industrialization, industrial remains witness local industrial iteration, urban construction, and social development. They promote regional economic rise and population agglomeration. They also carry regional culture and enterprise spirit. They can continue local industrial context, shape regional cultural symbols, and strengthen public cultural identity. This is socially significant for improving the local spiritual and cultural system and inheriting local industrial civilization.

(3) B3 Scientific and technological value. Scientific and technological value is evaluated through three sub-items: advancement of production technology, advancement of building structure, and advancement of supporting equipment. Production technology focuses on the production process, processing technology, and production system of the industrial category. It judges technological innovation, advanced level, and scarce value in the corresponding era and industry. Building structure focuses on the scientificity and innovation of structural design, spatial creation, and construction techniques. It reflects the construction technology level of industrial buildings in a specific period. Building equipment focuses on retained industrial equipment, electromechanical systems, and production facilities. It examines equipment installation, operation and maintenance, and supporting adaptation. This is an important physical basis for studying modern industrial science and technology.

(4) B4 Artistic value. Artistic value includes two dimensions: unique aesthetics of industrial buildings and broad architectural artistic value. Unique aesthetics focuses on the design language of modern industrial buildings. It relies on building volume, facade texture, structural lines, and spatial order to present practical, plain, and rational industrial aesthetics. This differs from civil buildings. Broad architectural artistic value starts from the building itself. It relies on overall shape, facade design, structural details, architectural style, and proportional scale. It reflects the design aesthetic orientation, construction craftsmanship, and artistic style of industrial buildings in a specific historical period.

(5) B5 Economic value. Economic value is judged from three dimensions: structural integrity, flexibility of space use, and future pedestrian flow attraction. Structural integrity determines the basic cost and renovation feasibility of revitalization. More complete structures give greater economic advantage for low-intervention renewal. Flexibility reflects functional adaptability and renovation plasticity. Remains adaptable to multiple business formats have higher reuse potential. Future pedestrian flow attraction relies on industrial cultural characteristics and scarce resources. It determines long-term economic value in cultural tourism, business operation, and industrial driving. It is an important basis for improving the quality and efficiency of stock industrial assets.

(6) B6 Integrity value. Integrity value is evaluated through three aspects: integrity of production process, degree of archival

material retention, and integrity of building preservation[13]. Production process integrity refers to whether the site, space, and layout retain the original functional sequence and process logic, and whether they can restore the modern industrial production mode. Archival material retention measures the completeness and authenticity of construction historical materials, production records, historical documents, and image materials. Building preservation integrity focuses on core buildings, structures, component details, and site texture. More intact buildings and details mean higher original integrity and conservation value.

After classifying and summarizing the first-level indicators, the Delphi method was used for correction. Twenty relevant experts and scholars were interviewed. A complete evaluation system was obtained, with the value evaluation of the architectural remains of the Tianfu Coal Mine Machine Repair Plant as the target layer, the six major values as the criterion layer, and 15 evaluation factors as the indicator layer (Table 1).

2.3 Weight calculation

This study invited experts and scholars in industrial archaeology, architectural history and theory, cultural heritage conservation, and urban renewal, as well as local cultural tourism staff, to form an expert review group (15 people). Using the Saaty 1−9 scale, experts compared indicators at the same level and scored their relative importance[14-15]. This produced the A−B and B−C judgment matrices. Data organization and matrix calculation produced the value judgment matrix and criterion layer weights (Table 2).

The criterion layer weights show that historical value has the highest proportion (0.296 5), followed by scientific and technological value (0.183 2), economic value (0.163 2), and integrity value (0.151 2). Social value (0.107 9) and artistic value (0.098 0) are lower. Experts generally believe that historical value should lead subsequent reuse. While preserving historical authenticity, the industrial technological attributes should be highlighted. Original production processes, mechanical equipment, and industrial structural features should be retained and displayed. The unique scientific and technological characteristics of the plant should be emphasized. The well-preserved architectural remains should support economic recovery and aesthetic improvement.

Indicator layer weights show that age background and history-related events and figures are the core of the machine repair plant. Space renovatability and building preservation determine reuse feasibility. Production processes and supporting equipment remains embody industrial technological identity. In future conservation and renewal design, protecting historical and cultural value while promoting regional economic development through reuse will be the top priority.

2.4 Grade classification using the matter–element extension model

The matter-element analysis method builds matter-element models and uses mathematical transformation. It depicts dynamic and variable characteristics and uses correlation functions for quantitative operations. This enables scientific data analysis and decision evaluation. The method handles both qualitative and quantitative indicators, simplifies research steps, and offers simple operation, strong operability, and clear results.

This study encompasses six aspects, namely history, society, science and technology, art, economy, and integrity, and 15 indicators.

Table 1 Value evaluation table of the architectural remains of the Tianfu Coal Mine Machine Repair Plant

Target layer A	Criterion layer B	Indicator layer C
Value evaluation of the architectural remains of the Tianfu Coal Mine Machine Repair Plant	B1 Historical value	C1 Historical background and age
		C2 Famous historical figures or events
	B2 Social value	C3 Contribution to regional development
		C4 Empowerment of local spiritual culture
	B3 Scientific and technological value	C5 Advancement of production technology
		C6 Advancement of building structure
		C7 Advancement of building equipment
	B4 Artistic value	C8 Unique aesthetics of industrial buildings
		C9 Broad architectural artistic aesthetics
	B5 Economic value	C10 Structural integrity
		C11 Flexibility of space use
		C12 Future pedestrian flow attraction
	B6 Integrity value	C13 Integrity of production process
		C14 Archival material retention
		C15 Building preservation integrity

Table 2 Weight distribution of the evaluation system of the Tianfu Coal Mine Machine Repair Plant

Target layer	Criterion layer B	Weight Wi	Indicator layer C	Relative weight	Weight W_i
Value evaluation of the architectural remains of the Tianfu Coal Mine Machine Repair Plant	B1 Historical value	0.296 5	C1 Historical background and age	0.500 0	0.148 3
			C2 Famous historical figures or events	0.500 0	0.148 3
	B2 Social value	0.107 9	C3 Contribution to regional development	0.750 0	0.080 9
			C4 Empowerment of local spiritual culture	0.250 0	0.027 0
	B3 Scientific and technological value	0.183 2	C5 Advancement of production technology	0.443 4	0.081 2
			C6 Advancement of building structure	0.169 2	0.031 0
			C7 Advancement of building equipment	0.387 4	0.071 0
	B4 Artistic value	0.098 0	C8 Unique aesthetics of industrial buildings	0.750 0	0.073 5
			C9 Broad architectural artistic aesthetics	0.250 0	0.024 5
	B5 Economic value	0.163 2	C10 Structural integrity	0.332 5	0.054 3
			C11 Flexibility of space use	0.527 8	0.086 1
			C12 Future pedestrian flow attraction	0.139 7	0.022 8
	B6 Integrity value	0.151 2	C13 Integrity of production process	0.319 6	0.048 3
			C14 Archival material retention	0.122 0	0.018 4
			C15 Building preservation integrity	0.558 4	0.084 4

Based on industrial remains assessment literature, field investigation, and expert guidance, the architectural remains are divided into five grades: Grade I (poor), Grade II (general), Grade III (good), Grade IV (excellent), and Grade V (outstanding). Grade I indicates extremely low comprehensive value. Grade II indicates general value. Grade III indicates good value. Grade IV indicates relatively high value. Grade V indicates extremely high value.

The matter-element extension model for the plant determined the classical domain and total field of each grade. It established the correlation function and used MATLAB to calculate the classical domain and total field, single-indicator correlation, comprehensive correlation, and eigenvalues. Tables 3 and 4 show the major values and comprehensive grades of the 18 architectural remains.

3 Conservation and reuse strategies for the Tianfu Coal Mine Machine Repair Plant

3.1 Demolition and retention of architectural remains

Industrial remains differ from industrial heritage. Not all industrial remains can be protected as industrial heritage. In the reuse and renovation of the plant, the primary issue is whether a building can be demolished or retained. This depends on the value of the architectural remains. For the Tianfu Coal Mine Machine Repair Plant, unless a criterion layer indicator reaches Grade V, the building can be demolished. Measures fall into three categories (Table 5).

3.2 Specific reuse building: Metalworking Workshop No. 2

The matter-element extension evaluation shows that Metalworking Workshop No. 2 has a comprehensive value grade of IV. According to Table 5, retention is recommended. This section uses Metalworking Workshop No. 2 to discuss how evaluation results guide reuse design for a single building.

3.2.1 Current situation and value assessment of Metalworking Workshop No. 2. Metalworking Workshop No. 2 and Metalworking Workshop No. 1 belong to the metal processing production area. Workshop No. 2 is one of the best-preserved large-span industrial buildings in the

Table 3 Major value evaluation table of the Tianfu Coal Mine Machine Repair Plant

Building name	B1 Historical value	B2 Social value	B3 Scientific and technological value	B4 Artistic value	B5 Economic value	B6 Integrity value
Bathhouse	II	II	II	II	II	II
Office building	III	II	II	II	II	IV
Boiler room	II	II	II	II	I	I
Laboratory	II	II	II	II	II	III
Grinding machine workshop	III	III	IV	IV	IV	IV
Power generation workshop	V	IV	V	IV	IV	III
Southeast corner factory building	V	III	IV	IV	IV	IV
Model and woodworking shop	II	III	III	III	II	II
Sun Yueqi's office	V	V	III	III	V	V
Metalworking Workshop No. 1	III	IV	V	V	V	IV
Metalworking Workshop No. 2	III	IV	V	V	V	IV
Ironworking shop	IV	III	III	III	IV	III
Belt lathe	II	IV	IV	IV	V	IV
Riveting and welding workshop	III	IV	V	IV	IV	IV
Mine car processing workshop	IV	III	III	III	III	III
Turner workshop	IV	III	IV	III	III	II
Material garage	II	II	I	II	II	III
Warehouse	IV	II	I	II	III	II

Table 4 Comprehensive grade table of the architectural remains of Tianfu Coal Mine

Building Name	Grade I	Grade II	Grade III	Grade IV	Grade V	Grade
Bathhouse	−0.259 8	0.123 8	−0.213 7	−0.408 9	−0.583 5	Grade II
Office building	−0.322 2	0.077 4	−0.091 3	−0.310 7	−0.520 6	Grade II
Boiler room	−0.127 4	0.048 8	−0.253 8	−0.514 9	−0.636 2	Grade II
Laboratory	−0.237 6	0.047 4	−0.133 7	−0.432 8	−0.580 6	Grade II
Grinding machine workshop	−0.499 5	−0.319 4	0.028 8	0.066 1	−0.329 9	Grade IV
Power generation workshop	−0.684 3	−0.575 4	−0.361 7	−0.019 9	−0.044 0	Grade IV
Southeast corner factory building	−0.663 8	−0.551 2	−0.316 4	0.129 6	−0.138 3	Grade IV
Model and woodworking shop	−0.299 9	0.129 5	−0.033 3	−0.383 4	−0.537 5	Grade II
Sun Yueqi's office	−0.638 0	−0.500 0	−0.338 3	−0.270 2	−0.005 6	Grade V
Metalworking Workshop No. 1	−0.639 5	−0.517 6	−0.239 5	−0.018 1	−0.100 5	Grade IV
Metalworking Workshop No. 2	−0.632 0	−0.473 8	−0.323 6	−0.070 6	−0.118 1	Grade IV
Ironworking shop	−0.473 9	−0.252 2	−0.000 0	−0.032 8	−0.357 4	Grade III
Belt lathe	−0.535 7	−0.364 4	−0.396 0	−0.135 7	−0.251 7	Grade IV
Riveting and welding workshop	−0.593 3	−0.410 8	−0.234 7	−0.009 0	−0.198 8	Grade IV
Mine car processing workshop	−0.447 8	−0.205 1	0.034 0	−0.103 9	−0.376 2	Grade III
Turner workshop	−0.432 5	−0.227 6	0.021 5	−0.090 5	−0.386 2	Grade III
Material garage	−0.242 7	−0.034 8	−0.271 4	−0.377 9	−0.553 1	Grade II
Warehouse	−0.262 1	−0.046 1	−0.199 6	−0.347 3	−0.536 1	Grade II

Table 5 Demolition and retention opinions

Grade of architectural remains	Demolition or retention opinion
Grades I–III	Unless one indicator is exceptionally prominent and reaches Grade V, such buildings can be selectively demolished or retained.
Grade IV	Retention is usually recommended.
Grade V	Retention is mandatory.

plant. Its main roof trusses, bent columns, and external wall enclosure are basically intact. The tall and open internal spatial pattern is fully preserved. Equipment bases, ground rails, and some production equipment remains for metal cutting are still in situ. The spatial organization logic of metalworking production is relatively completely retained. It is a physical witness of the "blanking—cutting—grinding—assembly" metal processing system.

Sub-item evaluation shows that scientific and technological value, artistic value, and economic value all reach Grade V. Social value and integrity value are Grade IV. Historical value is Grade III. The value structure is characterized by "prominence in technology, art, and economy". Its large-span roof truss structure reflects the construction technology of industrial buildings in a specific period. The retained metalworking process and equipment system carry high industrial technological identity. The industrial aesthetics formed by structural lines, spatial order, and facade texture have unique artistic expressiveness. High structural integrity and strong spatial flexibility give it top-ranking reuse potential in the plant. Historical value is relatively general. This indicates that the workshop's core value lies not in a single historical narrative, but in the technological entity and spatial potential.

This value structure means that reuse should not adopt "freezing-style" static protection. Instead, it should follow a reuse orientation led by "technology display, aesthetic experience, and functional revitalization". This matches the weight orientation in Section 2.3: "highlighting industrial technological attributes while preserving historical authenticity".

3.2.2 Functional positioning and renovation principles. Based on the building demolition and preservation suggestions proposed in Section 2.1 and relying on its outstanding scientific, technological, and artistic value, Metalworking Workshop No. 2 should be positioned as a composite functional space integrating industrial technology display, craft research and learning, and cultural and creative incubation. It can be called the "Tianfu Machine Repair Plant Industrial Technology Exhibition Hall".

The functional composition has three levels. The core exhibition space occupies the main large-span space. It displays the plant's process system, independent research and development achievements, and existing production equipment remains. The flexible partition of the large-span space allows cultural and creative studios, research and learning classrooms, and temporary exhibition halls. This echoes the spatial plasticity reflected by its Grade V economic value. Auxiliary functions include an entrance hall, light dining, and cultural and creative shops. They support gathering, rest, and operation.

Renovation should follow these principles:

(1) Authenticity and recognizability. It is necessary to preserve the authenticity of the main structure, process flow, and equipment remains. New components can be clearly distinguished from historical fabric in materials, colors, and construction methods. The relationship between old and new elements should be legible, and renovation works can be designed to be reversible.

(2) Minimal intervention. New functions can be implanted via low-impact measures. It is necessary to avoid destructive demolition and alteration of the main structure, and value carriers should be retained to the maximum extent.

(3) Highlighting technological aesthetics. Spaces and structures can be regarded as core exhibits. It is necessary to reduce decorative treatments, so as to highlight the order of large-span spaces and the rational beauty of industrial structures.

3.2.3 Specific reuse strategies for Metalworking Workshop No. 2.

(1) Structural retention and adaptive repair. It is necessary to carry out comprehensive structural inspection and appraisal of roof trusses, bent columns, and foundations. The main structural system can be kept unchanged. Locally damaged components can be repaired or reinforced. Roof renovation for insulation and waterproofing can be implemented without altering the roof truss form or overall appearance, and the historical skyline can be maintained.

(2) Spatial reorganization and functional implantation. The strategy of "large-space blank reservation + independent box implantation" can be adopted. The main large-span space can remain fully connected for permanent exhibitions and public activities. Cultural and creative studios and research and learning classrooms can be implanted as independent lightweight "boxes". The surplus clear height can be utilized to add partial mezzanines. The box structure is separated from the original factory structure and forms its own system. This can prevent damage to the historical structure and create a dialogue between old and new elements.

(3) Exhibition-oriented use of process and equipment remains. Retained equipment bases, ground rails, and lifting rails can be regarded as the "primary exhibits". Visiting routes can be organized around the metalworking process. Visitors can experience the process logic through spatial movement. Dynamic demonstrations of repairable equipment can be performed. A mode of static "exhibition + dynamic experience" can be formed to strengthen public understanding of modern mining machinery manufacturing technology.

(4) Facade and external space improvement. Inappropriate later additions and coverings can be cleared away. The original brick wall texture and door-and-window proportions can be restored. Damaged doors and windows can be repaired or replaced in accordance with the original style. The external site can be connected with Metalworking Workshop No. 1, and roads can be constructed to form a continuous public pedestrian system. Large mining machinery components can be displayed outdoors. The display of industrial remains can be extended from indoor to outdoor spaces to improve the overall spatial quality and attract pedestrian flow.

4 Conclusion

In summary, the reuse practice of Metalworking Workshop No. 2 shows that using the evaluation system as the decision-making basis can close the loop between conservation decisions and reuse design. The question of "whether to preserve" can be determined through grade evaluation. The issues of "how to preserve and how to use" can then be determined according to the sub-item value

structure. The "technology display + cultural and creative experience" reuse model balances historical context, industrial technology display, and regional economic development. It can serve as a reference for the reuse of other industrial heritage architectural remains.

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