Element System of Industrial Heritage Transformation in Turin: Collaborative Assessment and Design Strategies

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Abstract

The transformation of industrial heritage is a key issue in global urban renewal and sustainable development. With the decline of traditional manufacturing industries, numerous industrial heritage sites face challenges such as functional degradation, spatial vacancy, and reduced social integration. However, industrial heritage not only carries significant historical and cultural value but also holds great potential for adaptive reuse, contributing to innovation-driven urban development, industrial upgrading, and public cultural formation. Therefore, the critical question in contemporary industrial heritage research is how to systematically evaluate the influencing factors of transformation through a scientific assessment framework and optimize design strategies based on collaborative relationships.

This study first reviews the theoretical evolution of global industrial heritage conservation and transformation, focusing on the development of interdisciplinary integrated transformation models. It further analyzes the characteristics of cultural identity, adaptive reuse, and multi-level governance in the context of Italian industrial heritage transformation. By summarizing international case studies, the study identifies the core impact factors across social, economic, environmental, and cultural dimensions. Based on these findings, a comprehensive assessment framework is constructed, grounded in the collaborative interaction of key transformation elements, providing theoretical support for subsequent case studies and design strategies.

The research then selects Turin, Italy, as the case study area, analyzing three representative industrial heritage transformation projects—Parco Dora, OGR Innovation Hub, and the Lingotto Complex. Utilizing Social Network Analysis (SNA), a collaborative evaluation model is developed to quantify the interrelations among different transformation factors. The findings reveal that successful industrial heritage transformations typically rely on the synergy among cultural, economic, environmental, and social elements, with distinct variations in network structures across different transformation models. For instance, Parco Dora, which emphasizes ecological restoration, exhibits stronger environmental-social synergies, whereas OGR Innovation Hub achieves transformation through a culture-economy-governance collaborative mechanism.

Based on the evaluation results, this study proposes five key transformation strategies: mixed-function and spatial diversity, culture-driven industry regeneration, green infrastructure integration, historical memory and modern innovation fusion, and multi-level collaborative governance. These strategies are further implemented in the Mirafiori Factory transformation project, establishing a design framework driven by collaborative synergies. The core design interventions include modular prefabricated inter-column units, open and shared cultural spaces, an ecologically sustainable central atrium, optimized urban interfaces and site planning, and a spatial collaborative governance model. These strategies aim to enhance spatial adaptability, resilience, and long-term sustainability.

The innovation of this study lies in the establishment of a systematic framework for industrial heritage transformation, integrating Social Network Analysis (SNA) into the evaluation process to quantitatively reveal the collaborative relationships among key transformation elements. Furthermore, by exploring spatial design strategies informed by collaborative relationships, this research promotes a shift from singular conservation approaches to multi-functional adaptive transformation, ensuring the long-term value realization of industrial heritage within the framework of sustainable urban development. The findings not only apply to the case of Turin but also provide a reference for industrial heritage transformation practices worldwide.

Keywords: Industrial heritage transformation; collaborative assessment; element system; social network analysis; design strategy

Catalogue

Abstract II

Catalogue 1

1 Introduction 1

1.1 Research Background 1

1.1.1 Industrial Heritage Transformation as a Key Focus of Global Urban Renewal 1

1.1.2 The Complexity of Multi-Element Collaboration in Industrial Heritage Transformation 2

1.1.3 Research Significance of Turin's Industrial Heritage Transformation Projects 2

1.2 Research Scope and Concept Definitions 3

1.2.1 Industrial Heritage Transformation 3

1.2.2 Element System 4

1.2.3 Collaborative Assessment 5

1.3 Research Objectives and Significance 6

1.3.1 Research Objectives 6

1.3.2 Research Significance 7

1.4 Research Methodology and Framework 8

1.4.1 Research Methodology 8

1.4.2 Research Framework 9

2 Literature Review on Industrial Heritage Transformation 10

2.1 Theoretical Evolution of Global Industrial Heritage Conservation and Transformation 10

2.1.1 The Rise of Industrial Heritage Conservation Concepts 10

2.1.2 Introduction of Interdisciplinary Theories 14

2.1.3 The Development of Contemporary Integrated Transformation Models 19

2.2 Localization Characteristics of Italy's Industrial Heritage Transformation Strategies 25

2.2.1 Balancing Cultural Identity and Historical Conservation 26

2.2.2 Diversification of Adaptive Reuse Strategies...29
2.2.3 Collaborative Operation of Multi-Level Governance Models 32
2.3 Systematic Exploration of Industrial Heritage Assessment Methods 35
2.3.1 Representative Assessment Methods and Tools.......................................35
2.3.2 Construction of a Multidisciplinary Cross-Evaluation Model 43
2.3.3 Localization and Innovation in the Assessment of Industrial Heritage in Italy...51
2.4 Comprehensive Theoretical Framework: Theoretical Support for Elemental System Synergistic Evaluation..58
2.4.1 System Theory and Synergetics: A Holistic Understanding of Transformation..59
2.4.2 Sustainable Development Theory: Long-Term Value Assessment in Industrial Heritage Transformation...62
2.4.3 Multi-Level Governance Theory: Transformation Policies and Social Mechanisms 64
2.4.4 Complex Adaptive Systems Theory: Dynamic Evaluation of Transformation...68
2.5 Summary of This Chapter 71
3 The Elemental System Construction of Industrial Heritage Transformation 73
3.1 Extraction of Reference Elements...73
3.1.1 Key Reference Documents...73
3.1.2 Element Extraction and Analysis 77
3.1.3 Element Screening and Integration...81
3.2 Evaluation Dimension Classification 83
3.2.1 Social Well-being Dimension..84
3.2.2 Economic Development Dimension..84
3.2.3 Environmental Sustainability Dimension..85
3.2.4 Cultural and Social Governance Dimension 86
3.3 Element System Integration 87
3.4 Universality of the Element System 91
4 The Spatial Structure and Development Background of Turin’s Industrial

Heritage Transformation 93
4.1 Development Background of Turin’s Industrial Heritage Transformation .93
4.1.1 The Industrial Development History of Turin 94
4.1.2 The Spatial Distribution and Characteristics of Turin’s Industrial Heritage 98
4.1.3 The Master Plan for Industrial Heritage Transformation: The "Spina Centrale" Project 101
4.2 Typical Industrial Heritage Transformation Models and Case Studies.......104
4.2.1 Brownfield Ecological Regeneration Model: The Transformation of the Dora River Industrial District 104
4.2.2 Cultural and Creative Industry Integration Model: OGR Workshop Redevelopment 107
4.2.3 Mixed-Use Complex Redevelopment Model: The Transformation of Lingotto Factory 110
4.3 Overall Characteristics of Turin’s Industrial Heritage Transformation.....113
4.3.1 Diversification of Transformation Models 114
4.3.2 The Synergistic Relationship Between Industrial Heritage Conservation and Urban Renewal 115
4.3.3 Limitations and Challenges of Turin’s Industrial Heritage Transformation 117
5 Collaborative Assessment System for Industrial Heritage Transformation Based on Social Network Analysis 120
5.1 Constructing a Collaborative Evaluation Framework Using Social Network Analysis 120
5.2 Collaborative Evaluation Data Collection 125
5.3 Synergy Evaluation Analysis Indicators 127
5.4 Analysis of Synergy Evaluation Results in Case Studies...........................129
5.4.1 Dora River Industrial Area Transformation Synergy Assessment 129
5.4.2 OGR Railway Repair Workshop Transformation Synergy Assessment .134
5.4.3 Lingotto Factory Transformation Synergy Assessment 139
5.4.4 Comparative Analysis of the Three Cases...144
5.5 Design Strategy Synthesis 150

6 Design of Mirafiori Industrial Site Based on Element System Synergy 155
6.1 Industrial Heritage Transformation Strategies Aimed at Element System Synergy 155
6.1.1 “Reversibility” Element Synergy: Mixed-Use Functionality and Spatial Diversity 157
6.1.2 "Structural Compatibility" Element Synergy: Culture-Driven Industry Regeneration 160
6.1.3 "System Circularity" Element Synergy: Integration of Green Infrastructure 164
6.1.4 "Sense of Identity" Element Synergy: Fusion of Historical Memory and Modern Innovation 168
6.1.5 "Collective Growth Potential" Element Coordination: Multi-Level Collaborative Governance 172
6.2 Project Background 176
6.3 Adaptive Redevelopment Design of the Mirafiori Industrial Complex in Turin Based on Transformation Strategies 180
6.3.1 Creating "Reversibility": Modular Column-Bay Units 180
6.3.2 Enhancing "Structural Compatibility": Shared Cultural Program Planning 186
6.3.3 Strengthening "System Circularity": Eco-Sustainable Atrium......190
6.3.4 Reinstating "Sense of Identity": Urban Primary Interface Design 193
6.3.5 Developing "Collective Growth Capacity": Spatial Collaborative Governance Model 197
6.4 Design Summary 202
7 Research Conclusion 204
7.1 Research Summary 204
7.2 Research Limitations and Future Prospects 206
References 209
Appendix A Collaborative Assessment Scale for Industrial Heritage Transformation 213
Appendix B Design Drawings 214

1 Introduction

1.1 Research Background

1.1.1 Industrial Heritage Transformation as a Key Focus of Global Urban Renewal

With the acceleration of global urbanization, especially since the late 20th century, many traditional manufacturing hubs have experienced industrial decline, leading to the abandonment or underutilization of numerous industrial heritage sites. These industrial heritage sites not only represent the industrial history of cities but also carry significant cultural value. Therefore, how to scientifically repurpose these sites to meet the demands of modern urban development has become a key issue in global urban renewal and sustainable development.

In the process of urban renewal, the adaptive reuse of industrial heritage is not only about physical space transformation but also involves cultural preservation, industrial upgrading, and social integration. Many countries have adopted innovative strategies to revitalize abandoned industrial sites. For example, the Zollverein Industrial Complex in Germany has been successfully transformed into a cultural and creative hub, while the High Line Park in the United States has repurposed an abandoned elevated railway into an attractive urban public space. These cases demonstrate that well-planned industrial heritage transformation strategies can promote economic revitalization, enhance urban competitiveness, and improve residents' quality of life.

In recent years, China has also strengthened the conservation and adaptive reuse of industrial heritage. However, challenges remain in the transformation process. For example, due to market-driven factors, some industrial heritage projects have been excessively commercialized, weakening their historical and cultural value. Additionally, homogeneous transformations are prevalent, making many projects lack uniqueness. In March 2023, the Ministry of Industry and Information Technology of China issued the National Industrial Heritage Management Regulations, emphasizing ecological protection, holistic conservation, and sustainable development in industrial heritage reuse to achieve dynamic inheritance and rational utilization.

1.1.2 The Complexity of Multi-Element Collaboration in Industrial Heritage Transformation

The transformation of industrial heritage is not merely a single-dimensional spatial renovation but involves a multi-faceted collaboration across historical conservation, cultural inheritance, economic development, social participation, and environmental sustainability. The transformation process can be viewed as a systemic project of multi-element collaboration, requiring the establishment of close interactions among various elements to ensure sustainable transformation.

Because industrial heritage transformation involves multiple domains, its process requires interdisciplinary collaboration. Disciplines such as architecture, urban planning, history, sociology, economics, and environmental science all play critical roles in the transformation of industrial heritage. Moreover, multiple stakeholders—including government agencies, private enterprises, cultural organizations, and community residents—must collaborate to ensure the success of transformation projects.

In contemporary society, industrial heritage transformation is no longer merely a technical task but rather a process involving consensus-building, social participation, and stakeholder balance. A successful transformation must strike a balance between historical and cultural value preservation and socio-economic needs, while achieving overall optimization through collaborative mechanisms. The complexity of these interactions makes it difficult for traditional single-factor assessment methods to accurately measure transformation outcomes. Therefore, it is necessary to introduce collaborative assessment methods to analyze the synergy among transformation elements.

1.1.3 Research Significance of Turin's Industrial Heritage Transformation Projects

As one of Italy's major industrial centers, Turin has long played a significant role in automobile manufacturing, mechanical engineering, and heavy industry production. As the birthplace of FIAT, Turin witnessed the golden era of Italy's industrialization. However, with global economic restructuring and industrial upgrading, Turin's traditional industries have gradually declined, leading the city to face dual challenges of industrial restructuring and urban space renewal. Consequently, the rational transformation and adaptive reuse of industrial heritage in Turin has become a core issue in the city's current urban development strategy.

To address these challenges, the Turin municipal government, in collaboration with various social and private entities, has explored and implemented a series of industrial heritage transformation projects. Among them, Parco Dora, OGR Innovation Hub, and Lingotto Complex are considered landmark cases of Turin's industrial heritage transformation. These projects not only encompass diverse transformation models such as ecological restoration, cultural innovation, and industrial upgrading, but also involve multi-stakeholder governance, including government agencies, private enterprises, academic institutions, and community organizations. The success of these cases provides valuable insights and reference models for global industrial heritage transformation.

The industrial heritage transformation in Turin not only demonstrates how to balance historical and cultural preservation with modern functional demands but also highlights how collaborative governance mechanisms can enhance the social value and economic vitality of industrial heritage. In its transformation process, Turin has adopted a multi-layered governance model, combining government leadership, private investment, academic support, and community engagement, forming a multi-level, multi-stakeholder urban renewal mechanism.

Moreover, despite the progress made in Turin's industrial heritage transformation, challenges remain in areas such as environmental restoration, social inclusivity, and cultural identity. Some transformation projects, while generating economic benefits, may not fully address the cultural needs of local communities or may suffer from imbalanced resource allocation in environmental governance. Therefore, a systematic analysis of Turin's industrial heritage transformation can provide deeper insights into the key factors affecting the success or failure of such transformations and help identify future optimization strategies.

1.2 Research Scope and Concept Definitions

1.2.1 Industrial Heritage Transformation

Industrial heritage refers to industrial production facilities, sites, and related artifacts of significant historical, cultural, technological, and social value within the industrialization process. Industrial heritage includes not only factories, machinery, and warehouses as tangible cultural assets but also corporate culture, production techniques, social structures, and community memories as intangible cultural assets. As industrialization progressed, these industrial facilities not only generated immense economic value but also became important witnesses to urban development and social transformation. Therefore, how to effectively preserve and transform these heritage sites has become a key issue in global urban renewal.

The Nizhny Tagil Charter for the Industrial Heritage (2003) explicitly states that industrial heritage includes not only core production facilities but also related residential, social, and cultural spaces. This broadened definition expands the scope of industrial heritage transformation beyond architectural and spatial modifications, incorporating holistic adjustments across social, cultural, and environmental dimensions.

Thus, industrial heritage transformation refers to the repurposing, redevelopment, and functional conversion of underutilized or abandoned industrial heritage sites to align with contemporary urban development needs. The goal of transformation is to shift from traditional industrial production spaces to multifunctional, integrated urban spaces, rather than merely architectural renovation or functional repurposing.

1.2.2 Element System

An element system refers to an integrated framework composed of multiple interconnected and interactive elements. These elements are structured in a specific way to form an organic whole, collectively functioning to achieve a system's intended objectives. In the context of industrial heritage transformation, the primary focus of element system research is to analyze the interactions and synergies among various transformation elements, ensuring the sustainable adaptive reuse of industrial heritage.

One of the core objectives of this study is to establish an element system framework for industrial heritage transformation, revealing how different elements interact throughout the transformation process and exploring strategies to enhance their synergies. These elements span social, economic, environmental, and cultural dimensions. This study argues that the successful transformation of industrial heritage does not rely solely on the optimization of individual elements but rather on their collaborative interactions. For example, the introduction of cultural industries can stimulate economic revitalization, while economic growth can, in turn, support the improvement of public service infrastructure. Thus, analyzing the element system not only helps identify the independent contributions of each element but also offers insights into collaborative optimization, providing a scientific foundation for the sustainable transformation of industrial heritage.

1.2.3 Collaborative Assessment

Collaborative assessment is a multi-dimensional and multi-element evaluation approach aimed at analyzing the interrelationships, synergies, and overall effectiveness of different elements, revealing the operational mechanisms and optimization paths of complex systems. This assessment method is derived from Systems Theory and Synergetics, emphasizing how interactions among various elements influence the overall performance of a system.

In the study of industrial heritage transformation, collaborative assessment not only evaluates the performance of individual elements but also focuses on the interactions among different elements and their impact on the overall transformation outcomes. This method combines qualitative analysis and quantitative evaluation, scientifically quantifying the synergies among elements to provide data-driven support for optimizing industrial heritage transformation designs. The collaborative assessment methodology in this study consists of the following key steps:

Identifying Key Elements: Determining the most influential elements in industrial heritage transformation, such as cultural conservation, economic development, and environmental restoration.

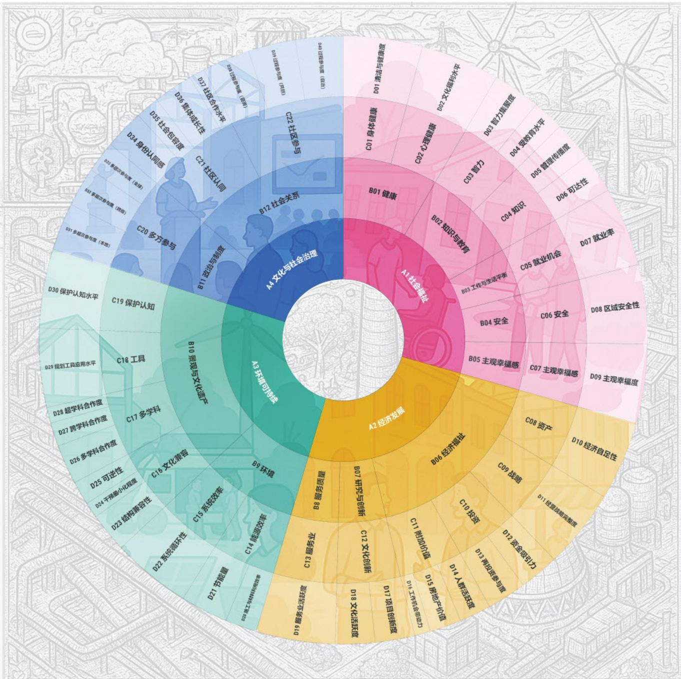


Figure 1.1 Dashboard of the Synergistic Evaluation Element System

Source: Drawn by the Author

Analyzing Synergies Among Elements: Utilizing Social Network Analysis (SNA) and other tools to construct element collaboration networks, quantifying the interactions among elements.

Assessing System Collaboration Level: Using synergy analysis to determine whether functional imbalances or resource misallocations exist, and evaluating the effectiveness of the current transformation plan.

Optimizing Transformation Pathways: Based on collaborative assessment results, identifying bottlenecks and opportunities within the system to propose targeted optimization strategies, enhancing overall performance.

By employing a collaborative assessment approach, this study uncovers the dynamic relationships, synergy levels, and optimization opportunities within the element system of industrial heritage transformation. This method not only enhances the scientific precision of transformation designs but also provides quantifiable decision-making support for the future conservation and adaptive reuse of industrial heritage.

1.3 Research Objectives and Significance

1.3.1 Research Objectives

The transformation of industrial heritage involves the synergy of cultural, economic, social, and environmental factors. A critical issue in current industrial heritage research is how to systematically evaluate the relationships among these elements and optimize their collaborative effects. Based on case studies of industrial heritage transformation in Turin, this study explores a collaborative assessment method for industrial heritage element systems and proposes optimized design strategies. The specific research objectives include the following four aspects:

Establish a collaborative assessment framework for industrial heritage transformation, integrating Systems Theory, Synergetics, and Social Network Analysis (SNA) to develop a framework based on element systems, quantitatively revealing the interactions among different elements.

Analyze transformation models and their synergy characteristics in industrial heritage, using Parco Dora, OGR Innovation Hub, and Lingotto Complex as case studies to examine key elements and their collaborative relationships in different transformation models.

Optimize the collaborative design strategies for industrial heritage transformation, identifying key synergies in transformation projects based on assessment results and proposing targeted spatial design strategies to enhance social, economic, and environmental value.

Explore scalable models for industrial heritage transformation, summarizing key influencing factors based on Turin's case studies and assessment results, and proposing adaptable transformation models applicable to different urban contexts, providing both theoretical insights and practical references for global industrial heritage conservation and reuse.

1.3.2 Research Significance

This study holds significant value in both theoretical and practical dimensions, offering an innovative perspective on the assessment of industrial heritage transformation and providing a scientific foundation for future design strategies.

First, on a theoretical level, this study makes contributions in the following three areas:

Developing a collaborative assessment framework for industrial heritage transformation: While previous studies often focused on single-element analysis (e.g., cultural preservation, economic value), this research establishes a collaborative assessment system, filling a gap in the quantitative analysis of multi-element interactions.

Expanding the application of Social Network Analysis (SNA) in industrial heritage research: Current industrial heritage assessment methods rely heavily on expert judgment and qualitative analysis. This study integrates SNA methodologies to uncover the collaborative network structure among elements using a data-driven approach, providing a replicable quantitative tool for future research.

Integrating urban renewal theories to deepen research on the sustainable transformation of industrial heritage: This study explores how industrial heritage can balance economic development, cultural preservation, and social needs, offering new theoretical insights for sustainable urban renewal.

Second, on a practical level, the findings of this study provide direct guidance for the planning and design of industrial heritage transformation in two key areas:

Providing a quantifiable assessment tool for industrial heritage transformation: Traditional transformation projects often rely on expert judgment without quantitative evaluation tools. This study introduces an SNA-based collaborative assessment tool, offering data-driven decision-making support for governments and planning authorities.

Optimizing spatial design strategies for industrial heritage transformation: Based on case studies and collaborative assessment results, this study proposes spatial design principles applicable to different types of industrial heritage, providing practical guidance for future transformation projects.

In summary, this study not only advances theoretical research on industrial heritage transformation but also provides a scientific framework and methodology for future practical applications.

1.4 Research Methodology and Framework

1.4.1 Research Methodology

This study adopts a research methodology that combines literature analysis, case studies, Social Network Analysis (SNA), and design practice, offering a comprehensive perspective on the collaborative assessment and design strategies of industrial heritage transformation.

First, through literature analysis, the study reviews the theoretical evolution and practical models of industrial heritage transformation worldwide, focusing on research progress in industrial heritage conservation, interdisciplinary assessment systems, sustainable reuse, and collaborative governance.

Second, using case study methodology, the research selects three representative industrial heritage transformation projects in Turin, Italy—Parco Dora, OGR Innovation Hub, and Lingotto Complex—to analyze their element collaboration models, design strategies, and socio-economic impacts.

Third, applying Social Network Analysis (SNA), the study quantifies the collaborative relationships among elements in different industrial heritage transformation projects, constructing a collaborative assessment model to identify key influencing factors and interaction patterns in successful transformations.

Finally, based on the case studies and assessment results, the research engages in design practice exploration, proposing collaborative design strategies applicable to industrial heritage transformation. The Mirafiori Factory transformation proposal serves as a practical implementation to validate how the collaborative assessment approach can guide design optimization.

1.4.2 Research Framework

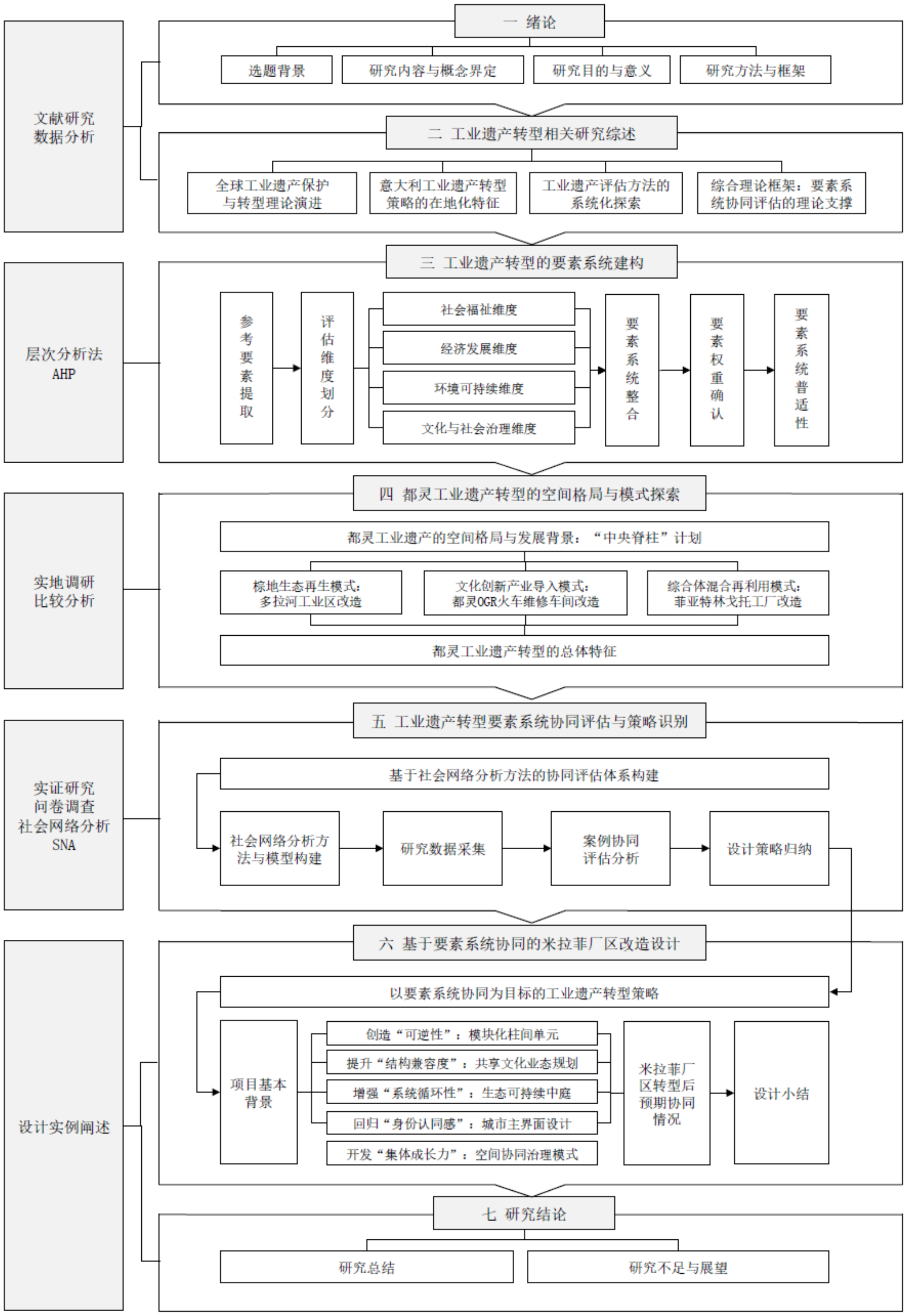


Figure 1.2 Thesis Framework

Source: Drawn by the Author

2 Literature Review on Industrial Heritage Transformation

2.1 Theoretical Evolution of Global Industrial Heritage Conservation and Transformation

2.1.1 The Rise of Industrial Heritage Conservation Concepts

The concept of industrial heritage conservation originated in mid-20th century Europe. As industrialization progressed, many early industrial facilities were gradually decommissioned or abandoned, leading to a reevaluation of their historical and cultural significance. Against this backdrop, the theories of historic building conservation and cultural heritage protection gradually extended to the field of industrial heritage, promoting awareness of its importance and necessity.

Early industrial heritage conservation focused primarily on the preservation and restoration of physical spaces, with particular emphasis on the maintenance of buildings, equipment, and infrastructure. However, as research deepened, scholars began to recognize that industrial heritage is not merely a collection of tangible artifacts but also embodies unique social relationships, cultural memory, and technological innovations. Consequently, a more comprehensive conservation strategy became necessary.

Table 2.1 The Emergence of Industrial Heritage Conservation Concepts

Stage	Core Content	Key Milestones / Representative Events	Theoretical / Institutional Support	Major Contributions
Conceptual Origins	Industrial heritage first recognized as a category of cultural heritage	1955: Michael Rix introduced the term "industrial heritage"	Industrial archaeology, historic building conservation	Initiated systematic research on industrial heritage protection; expanded the boundaries of cultural heritage
Early Conservation Practices	National surveys and conservation initiatives in the UK and US	Ironbridge International Conference (UK); Historic American Engineering Record (HAER, US)	*Venice Charter* (1964), *Burra Charter* (1979)	Emphasized authenticity, integrity, and social meaning; advanced the theory of adaptive reuse

Formation of International Organizations	Internationalization and institutionalization of conservation efforts	1978: TICCIH founded; 1986: Ironbridge Gorge designated World Heritage Site	TICCIH, ICOMOS, UNESCO	Established a global protection network and promoted transnational exchange of experience
Establishment of International Frameworks	Integration of industrial heritage into cultural heritage legislation	*World Heritage Convention* (1972), *Nizhny Tagil Charter* (2003), *Dublin Principles* (2011)	ICOMOS × TICCIH guiding documents	Clarified the value system of industrial heritage and unified global conservation concepts
Expansion of Value Categories	Broadened from physical preservation to include social, cultural, and technological dimensions	The "Three Core Values": historical, technological, and socio-cultural	*Nizhny Tagil Charter*	Provided a value foundation for assessment systems and reuse policies
Evolution of Conservation Methods	Shifted from static preservation to adaptive reuse and public engagement	Building restoration, functional repurposing, educational exhibitions, community participation	*Dublin Principles*, Sustainable development philosophy	Integrated industrial heritage into urban development and cultural dissemination; enhanced social identity

Source: Compiled by the author

（1）The Formal Introduction of the Industrial Heritage Concept

Abandoned factories and mines following the Industrial Revolution were initially not regarded as cultural heritage. In the 1950s, interest in industrial archaeology emerged in the United Kingdom, where a large number of historic industrial buildings faced the threat of demolition. This situation prompted a group of scholars and enthusiasts to conduct systematic research and advocate for the protection of industrial sites.

The term "industrial heritage" was first introduced in 1955 by Michael Rix, a historian at the University of Birmingham. Based on industrial archaeology theories, Rix argued that industrial heritage should be considered an integral part of cultural heritage, deserving the same level of protection as traditional architectural heritage. This perspective challenged the conventional focus on classical buildings and historical sites, bringing factories, mines, railways, bridges, and canals into the realm of heritage conservation.

During the 1960s and 1970s, as cultural heritage movements gained momentum, industrial archaeology developed into an independent field, leading to nationwide industrial heritage surveys in the United Kingdom and the United States, such as the Industrial Monuments Survey in the UK and the Historic American Engineering Record (HAER) in the US.

In 1973, the first international conference on industrial heritage conservation was held in Ironbridge, UK, marking the beginning of international cooperation in this field. In 1978, the International Committee for the Conservation of the Industrial Heritage (TICCIH) was formally established as a global organization dedicated to promoting industrial heritage conservation, advancing theoretical research, practical experiences, and policy recommendations.

The establishment of TICCIH marked the transition of industrial heritage conservation into a systematic research discipline, officially recognizing it as an independent branch within cultural heritage conservation. Subsequently, the concept of industrial heritage gained international recognition. Some early industrial sites were listed as World Heritage Sites, such as Ironbridge Gorge in Shropshire, UK, which was inscribed on the UNESCO World Heritage List in 1986. This signified growing recognition of the cultural value of industrial heritage.

By the 1980s, industrial heritage conservation theories began to spread across Europe and North America, and scholars and policymakers gradually realized that industrial heritage should not be regarded merely as historical relics but as symbols of industrial society and carriers of social memory.

During this period, several countries developed initial conservation frameworks and theoretical foundations. Simultaneously, existing cultural heritage conservation guidelines began to be applied to industrial heritage protection, such as The Venice Charter (1964) and The Burra Charter (1979). The Venice Charter, originally aimed at historic buildings, introduced the concepts of authenticity and integrity, which were later extended to industrial heritage conservation. The Burra Charter, issued in 1979 by the Australia ICOMOS, emphasized the need to consider the social significance and functional value of cultural heritage, providing a theoretical basis for the adaptive reuse of industrial heritage.

These charters laid the foundation for modern industrial heritage conservation methodologies and stimulated discussions and practical applications in different countries.

（2）Establishment of the International Framework for Industrial Heritage Conservation

The 1972 UNESCO World Heritage Convention provided a legal framework for cultural heritage conservation, including industrial heritage. During the 1980s and 1990s, as research on industrial heritage conservation deepened, the international community began working towards a more systematic protection framework. Subsequently, ICOMOS (International Council on Monuments and Sites) and other international organizations developed guidelines incorporating industrial heritage into the broader cultural heritage system.

In 2003, TICCIH published The Nizhny Tagil Charter for the Industrial Heritage, establishing the fundamental principles of industrial heritage conservation. This charter became the key guiding document for global industrial heritage protection. The Nizhny Tagil Charter formally defines industrial heritage as

"The remains of industrial culture, which hold historical, technological, social, architectural, or scientific value. These remains include buildings and machinery, workshops, manufacturing plants, and factories, mines and processing sites, warehouses and storage facilities, power generation facilities, transportation infrastructure, and all underground structures. Additionally, social activity sites related to industry, such as workers' housing, places of worship, and educational institutions, are also included within the scope of industrial heritage."

This definition expanded the scope of industrial heritage, encompassing broader cultural and social factors. The Nizhny Tagil Charter also outlines the core values of industrial heritage. From a historical perspective, industrial heritage serves as tangible evidence of human society’s transition into the industrial age, documenting the process of industrialization and its profound socio-economic impact. Scientifically and technologically, industrial heritage reflects engineering and technological advancements across different periods. In terms of socio-cultural significance, industrial heritage carries the history of the working class, represents local cultural identity, and preserves the collective memory of urban development

The main strategies for industrial heritage conservation include different approaches. Physical conservation emphasizes maintaining and restoring architectural structures, equipment, and infrastructure to preserve their authenticity. Adaptive reuse promotes the functional repurposing of abandoned industrial heritage sites to integrate them into contemporary urban development and social needs. Cultural dissemination advocates for public education, exhibitions, and publications to raise awareness of the significance of industrial heritage.

The publication of The Nizhny Tagil Charter provided a unified theoretical foundation and practical guidelines for global industrial heritage conservation, influencing policy development in many countries. In 2011, ICOMOS and TICCIH jointly issued The Dublin Principles, further refining the guidelines for industrial heritage conservation and adaptive reuse. These documents emphasized the unique value and vulnerability of industrial heritage, urging countries to incorporate industrial heritage into legal protection frameworks and highlighting its role in extending resource lifecycles and promoting sustainable development.

Over several decades, an international framework for industrial heritage conservation—comprising legal instruments, conventions, and charters—has been gradually established. This framework now serves as a guiding structure for countries worldwide in developing their industrial heritage conservation and transformation policies.

2.1.2 Introduction of Interdisciplinary Theories

With the deepening of industrial heritage conservation concepts in the late 20th century, the traditional historic building conservation framework became insufficient to address the complex socio-economic functions of industrial heritage. To tackle this challenge, interdisciplinary theories have gradually been incorporated into industrial heritage research and practice, forming new assessment and transformation models. In particular, Cultural Landscape Theory, Adaptive Reuse Theory, and the Community-Based Approach have provided multidimensional methods and strategies for the protection and development of industrial heritage.

Table 2.2 Introduction of Interdisciplinary Theories into Industrial Heritage Conservation

Theory Name	Core Concept	Application Features and Significance

Cultural Landscape Theory	Emphasizes the holistic relationship between industrial heritage, environment, community, and history, adopting a landscape-oriented perspective.	Shifts from individual building restoration to regional landscape conservation; integrates ecology, culture, and spatial structure to foster diversified regional development.
Adaptive Reuse Theory	Revitalizes heritage sites by introducing new functions while respecting the original architectural character, achieving "new life for old buildings."	Advocates minimal intervention, functional transformation, and energy conservation; enhances integration of historical values and contemporary functions, boosting social and environmental benefits.
Participatory Governance Theory	Encourages the involvement of diverse stakeholders in heritage conservation and management, promoting community co-construction, collaborative governance, and public recognition.	Highlights bottom-up negotiation mechanisms; enhances legitimacy, inclusiveness, and long-term social sustainability of projects; strengthens sense of belonging and identity.

Source: Compiled by the author

（1）Cultural Landscape Theory

Cultural Landscape Theory emphasizes the holistic value formed through human-environment interactions. When introduced into the field of industrial heritage, this concept encouraged scholars to move beyond a focus on individual buildings and to consider industrial heritage within a broader environmental and historical context. Scholars have proposed that industrial heritage should be viewed as part of an "industrial cultural landscape", where the relationship between industrial heritage, surrounding nature, and local communities is examined from a landscape perspective. Moreover, cultural landscape conservation methods can be applied to the management of industrial heritage.

For example, Cimino's case study on Western mining landscapes demonstrated that the traditional approach of preserving individual structures is insufficient to interpret the complexity of such sites. Only by protecting these sites as integrated landscapes—considering their multiple values and continuous evolution—can the full significance of industrial landscapes be realized. The introduction of Cultural Landscape Theory has broadened the perception of industrial heritage, shifting the focus from physical artifacts to the environmental characteristics and cultural spirit associated with them. This transition has promoted the evolution of industrial heritage conservation from isolated monument preservation to integrated regional landscape conservation.

Cultural Landscape Theory has been widely applied in the conservation of industrial heritage. For instance, the Ruhr Industrial Region in Germany, once the country's most important coal and steel production base, faced large-scale abandonment due to industrial decline. Instead of adopting a simple architectural restoration strategy, the German government implemented a cultural landscape approach, preserving the overall environmental characteristics of industrial heritage while incorporating greening projects, cultural and artistic interventions, and ecological restoration. This approach established a symbiotic model between industry and ecology, maintaining the industrial identity of the Ruhr region while promoting economic diversification. Cultural Landscape Theory underscores the integrity and environmental adaptability of industrial heritage, providing new perspectives for shifting from individual building restoration to systemic regional protection and ecological integration.

（2）Adaptive Reuse

With the rise of the "revitalization of old buildings" movement, adaptive reuse has become a key strategy and theoretical foundation for industrial heritage transformation. Adaptive reuse emphasizes revitalizing buildings by introducing new functions while respecting their original architectural form and historical significance. This concept focuses on functional repurposing, spatial transformation, and usage modification, allowing industrial heritage to shift from traditional production facilities to new spaces that cater to modern social needs.

Since the late 20th century, heritage conservation perspectives have shifted from "static preservation" to "active utilization," positioning heritage reuse as a strategy for urban renewal and sustainable development. Research has shown that through adaptive reuse, abandoned industrial buildings can be transformed into publicly accessible and functionally viable spaces, extending their material lifespan while also stimulating regional revitalization. Binney and other scholars argued as early as 1990 that repurposing abandoned industrial buildings for societal use represents a path that combines economic revitalization with heritage conservation ethics[1]. The multiple benefits of adaptive reuse have been widely recognized. Economically, it is cost-effective and can stimulate regional economic growth. Culturally, it preserves historical continuity and prevents the cultural rupture caused by demolition and reconstruction. Environmentally, adaptive reuse reduces energy consumption by prioritizing human labor over new materials, making it a more sustainable approach. Thus, adaptive reuse has become a core guiding principle in industrial heritage transformation, providing a scientific methodology for injecting new functions into old industrial facilities.

The key principles of adaptive reuse include the Principle of Minimal Intervention, which advocates minimizing alterations to the original structure to maintain historical integrity and architectural character. Additionally, the principle of functional transformation and economic viability ensures that industrial heritage reuse strikes a balance between cultural value and long-term economic sustainability, ensuring social acceptance and operational feasibility.

A notable example is Ca l'Alier Innovation Center in Barcelona, Spain, originally a 19th-century textile factory that had long been abandoned. Through adaptive reuse, it was transformed into Barcelona's Urban Innovation Hub, serving as a key center for sustainable technology research and startup incubation. The renovation retained the original brickwork structure while integrating smart building technologies, such as solar panels, intelligent lighting, and rainwater collection systems, making it a zero-energy building. In addition to research and technology development spaces, the center also features community exhibitions and innovation workshops, aligning industrial heritage reuse with broader urban and social development goals.

Such cases demonstrate that adaptive reuse not only assigns new social value to industrial heritage but also fosters urban innovation and sustainability. By rationally repurposing industrial buildings, these projects preserve architectural authenticity while successfully adapting to modern needs, making them valuable resources in fields such as culture, technology, and education.

Figure 2.1 Renovated Ca l'Alier Innovation Center

Image Source: Barcelona Turisme

（3）Community-based Approach

Industrial heritage is closely linked to local community identity and collective memory, making social participation theory increasingly relevant in industrial heritage conservation and reuse. Social participation theory asserts that industrial heritage conservation should not be exclusively led by governments or experts, but should actively engage local communities, businesses, and NGOs to ensure that the reuse of industrial heritage aligns with local needs and remains sustainable in the long term.

In recent years, both academia and practitioners have recognized that involving stakeholders and local residents in industrial heritage projects enhances decision-making democracy and implementation effectiveness. Oevermann's study of the Oberschöneweide Industrial District in Berlin, Germany, illustrates that local communities strongly identify with industrial heritage. Although residents were able to participate in heritage reuse initiatives through government-provided engagement mechanisms and grassroots advocacy, limitations in participation channels still posed challenges[2]. This highlights the need for improved participation methods to achieve genuine community co-creation.

On a theoretical level, ICOMOS's Dublin Principles and other policy documents emphasize that multiple stakeholders should be involved in all phases of industrial heritage projects, from decision-making to management. This reflects the collaborative governance concept, shifting away from expert-dominated "authorized heritage discourse" towards multi-stakeholder dialogue and negotiation[3]. The introduction of social participation theory has encouraged a greater focus on human factors in industrial heritage transformation, fostering community workshops, public consultations, and volunteer activities to turn industrial heritage into a collectively shaped community asset. This interactive, people-centered approach not only enhances public recognition of projects but also infuses industrial heritage with new social value.

Community-based approaches emphasize local residents' active participation, transforming industrial heritage into an essential resource for community development. For example, in Amsterdam's Western Docklands, the industrial heritage revitalization process adopted a community consultation mechanism, allowing local residents, artists, and cultural organizations to engage in planning and decision-making. This resulted in the transformation of industrial buildings into public cultural spaces, strengthening social cohesion. In Bologna, Italy, the Art Manufacturing District project adopted a citizen participation framework, enabling community residents to collectively decide on renovation plans. This ensured that industrial heritage reuse not only fulfilled economic and cultural needs but also reinforced local identity and social inclusion.

The integration of the community-based approach has transformed industrial heritage revitalization from a government-led initiative into a collaborative process involving multiple stakeholders. This ensures that industrial heritage truly integrates into contemporary urban life and meets the diverse needs of society.

2.1.3 The Development of Contemporary Integrated Transformation Models

Entering the 21st century, the objectives of industrial heritage conservation have expanded beyond simple building restoration to encompass broader urban revitalization strategies. Industrial heritage is no longer merely regarded as a historical witness to industrial civilization; instead, it has been incorporated into urban planning, environmental management, and economic development frameworks, becoming a vital resource for sustainable urban transformation. Against this backdrop, industrial heritage conservation has increasingly intersected with emerging issues such as urban renewal, green sustainable development, and the creative economy, forming a new system of industrial heritage transformation. As countries continue to innovate in the conservation and adaptive reuse of industrial heritage, the field has evolved from traditional physical conservation to multifunctional, multidimensional, and interdisciplinary approaches.

Table 2.3 Contemporary Integrated Transformation Models of Industrial Heritage

Transformation Model	Core Strategy	Typical Significance
Urban Regeneration-Oriented	Incorporates industrial heritage into broader urban development strategies; promotes spatial regeneration and economic revitalization through multifunctional integration.	Revives urban vitality, avoids mono-functional use and spatial vacancy, enhances urban competitiveness and sense of place.
Green and Sustainable Development-Oriented	Emphasizes environmental protection, low carbon, energy efficiency, and ecological restoration, positioning industrial heritage as green infrastructure.	Aligns with SDGs and carbon neutrality strategies; achieves dual benefits of cultural value and ecological sustainability; addresses environmental and sustainability challenges.
Creative Economy-Oriented	Attracts creative industries by leveraging heritage spaces; transforms sites into platforms for innovation incubation and cultural production, fostering a distinctive “spirit of place.”	Enhances regional cultural influence and innovation capacity, stimulates creative vitality, and promotes the integration of urban transformation with the cultural economy.

Source: Compiled by the author

（1）Industrial Heritage and Urban Renewal

Industrial heritage plays a key role in the urban revitalization processes of many cities worldwide. As a testimony to the industrialization process, these heritage sites often occupy strategic urban spaces with high redevelopment potential and are increasingly recognized as valuable resources for urban renewal. In the post-industrial era, many cities have sought to revitalize declining areas by repurposing industrial sites through conservation-led redevelopment. Through innovative transformation practices, industrial heritage sites have been assigned new functions and reopened to the public, becoming an integral part of collective urban culture. Practical experience has shown that integrating industrial heritage into urban renewal offers multiple benefits: it preserves the unique character of cities while injecting new vitality into old urban districts. For instance, many former industrial areas have been successfully transformed into cultural and creative hubs or mixed-use commercial complexes, attracting foot traffic, investment, and regional economic growth. However, scholars such as Konior have cautioned that industrial heritage-driven urban renewal should not become overly elitist or follow a “one-size-fits-all" model[4]. Instead, redevelopment strategies should consider local needs and avoid homogeneous solutions.

In recent years, governments and urban planners have increasingly incorporated industrial heritage conservation into urban renewal policies, adopting multifunctional integration of culture, commerce, housing, and infrastructure to optimize urban structures and enhance urban functions. The typical models of industrial heritage-driven urban renewal include culture and arts-driven renewal, industry-upgrading renewal, and comprehensive urban renewal.

The culture and arts-driven renewal model repurposes industrial heritage into cultural centers or art districts, stimulating creative industry development. A notable example is La Confluence Industrial District in Lyon, France, once one of the city's main industrial hubs. Following industrial decline, many warehouses and factories were abandoned. The local government decided to redevelop the district into a cultural and creative industry cluster. By introducing museums, art galleries, cultural event spaces, and public art installations, the area successfully transitioned from a traditional industrial district to a cultural and creative hub. The project retained key industrial structures while integrating innovative design and functional transformation, attracting cultural and creative enterprises and tourists, making it a landmark in Lyon's modernization.

Figure 2.2 The Halle Girard in Lyon, France, Repurposed from a Factory

Image Source: ArchDaily

The industry-upgrading renewal model focuses on transforming industrial heritage into commercial, office, and residential complexes to boost regional industrial upgrading. An example is Pittsburgh's Strip District in the United States, originally a heavy industrial and warehouse zone that faced severe economic challenges following the decline of manufacturing. Through urban planning and industrial policy adjustments, the district has been redeveloped into a mixed-use area featuring commercial, retail, and residential spaces. Many industrial buildings have been repurposed into modern offices, apartments, and retail centers, attracting a new wave of technology and creative enterprises. The transformation has not only addressed spatial vacancy issues but also positioned the Strip District as a key driver of Pittsburgh's new economy.

The comprehensive urban renewal model adopts a cross-sectoral, multi-functional redevelopment approach to achieve sustainable transformation goals. A leading example is Scheepvaartkwartier in Rotterdam, Netherlands, once a significant port and industrial zone. As port functions relocated and modernized, the district transitioned into a mixed-use area featuring housing, offices, and commercial facilities. Throughout the redevelopment process, Rotterdam preserved historic industrial buildings while prioritizing ecological restoration, introducing green public spaces and pedestrian pathways. By integrating residential, commercial, cultural, and environmental elements, Scheepvaartkwartier achieved a sustainable transformation, becoming a model of green urban renewal in Europe. The redevelopment not only boosted economic growth but also enhanced environmental quality and residents' living conditions, offering valuable lessons for global urban renewal efforts.

These case studies demonstrate that industrial heritage transformation should not be limited to functional repurposing or building restoration alone. Instead, it should align with broader urban development strategies, fostering cultural, economic, and social revitalization. Through strategic planning and innovative design, industrial heritage can be revitalized to contribute to urban renewal and sustainable development.

（2）Industrial Heritage and Green Sustainable Development

Under the framework of global sustainable development, industrial heritage conservation has increasingly been integrated into green architecture, low-carbon cities, and sustainable urban development initiatives, emphasizing energy efficiency, low-carbon operations, and ecosystem restoration. Reusing existing buildings can significantly reduce construction waste and energy consumption, making it a tangible practice in circular economy and green development efforts. For example, structural reuse of old factory buildings is seen as a way to "store" the energy and materials previously invested in construction, thereby contributing to local and national sustainable development goals. Additionally, many former industrial sites suffer from environmental contamination, necessitating remediation efforts such as soil treatment and vegetation restoration to transform polluted brownfields into healthy ecological spaces.

Driven by the United Nations Sustainable Development Goals (SDGs) and the Paris Agreement on carbon neutrality, an increasing number of industrial heritage transformation projects have adopted green design strategies, including renewable energy integration, energy-efficient building retrofits, and ecological landscape restoration. Evaluating environmental performance has become a critical metric for industrial heritage projects, with assessments focusing on carbon footprint reduction, energy savings, and ecological improvements. This shift has expanded industrial heritage conservation beyond cultural concerns to a dual focus on culture and ecology, aligning with green and eco-city concepts.

A prime example is Zeche Zollverein in Germany, a UNESCO World Heritage Site that has implemented a series of green sustainable development measures. The transformation includes energy-efficient building renovations, such as integrating solar photovoltaic systems and smart lighting, significantly enhancing energy efficiency. The site also adopted ecological restoration strategies, converting abandoned land into green parks and implementing rainwater harvesting systems and ecological wastewater treatment facilities to mitigate urban heat island effects. Additionally, the redevelopment emphasized sustainable mobility, enhancing public transport accessibility and pedestrian-friendly pathways to promote low-carbon travel.

Figure 2.3 Ippolito Park in Germany with Green Sustainability Measures

Image Source: Zollverein Official Website

（3）Industrial Heritage and the Creative Economy

With the transformation of the global economic structure, the creative economy has gradually become a major driving force behind the adaptive reuse of industrial heritage. The creative economy emphasizes the development of culture, arts, design, and technology, industries that rely heavily on knowledge and innovation. Due to their unique spatial characteristics, industrial heritage sites often serve as ideal venues for creative industries. Many countries have explored the repurposing of abandoned industrial spaces into creative industry clusters, leveraging their historical ambiance to attract artists, designers, and cultural enterprises, thereby facilitating economic transformation. Cerisola's research suggests that rich historical heritage can stimulate creativity and drive economic growth, as cultural heritage "sparks curiosity and imagination, enhances innovation capacity, and ultimately leads to higher productivity."[5] A statistical study conducted in the United Kingdom found that for every one-unit increase in the density of historic buildings, the concentration of creative industry enterprises increased by 0.04 units. Moreover, the proportion of creative enterprises in historic districts was significantly higher than in ordinary neighborhoods[6]. These findings indicate that historical heritage environments attract creative talent and businesses.

Based on this understanding, numerous successful case studies have emerged. For instance, Castlefield in Manchester, UK, was once an important industrial hub during the early Industrial Revolution. During urban regeneration efforts, it was transformed into a cluster for cultural creativity, technology startups, and film production. By introducing creative studios, digital media centers, and technology incubators, Castlefield has become one of the core hubs of the creative economy in Northern England.

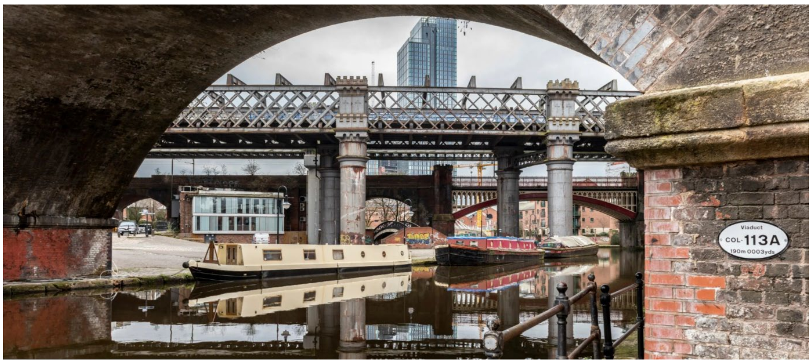


Figure 2.4 Current Status of Castlefield Industrial Area, UK

Image Source: National Trust Official Website

Similar examples of industrial heritage transformation can be found worldwide. Beijing's 798 Art District successfully repurposed a former factory into a contemporary art community, fostering a vibrant creative hub. New York's High Line Park revitalized an abandoned railway into a dynamic urban park, catalyzing the development of surrounding creative industries and commercial areas. Likewise, OGR in Turin, Italy, originally a large locomotive repair facility, was transformed into a center for arts and innovation, combining cultural exhibitions with technological innovation.

These projects demonstrate that the integration of industrial heritage and the creative economy generates a "1+1>2" effect, not only revitalizing underutilized assets but also fostering the growth of emerging cultural industries. From the perspective of the creative economy, industrial heritage transformation focuses on cultivating a unique "sense of place", transforming historical value into creative resources, and achieving a win-win scenario for both economic returns and cultural preservation. As the concept of creative cities gains traction, industrial heritage is increasingly recognized as a valuable cultural resource, and its role in the creative economy is becoming more significant.

The rise of the creative economy has opened up new possibilities for the revitalization of industrial heritage. Compared to traditional commercial development models, creative economy-driven adaptive reuse emphasizes cultural value exploration, social innovation, and industrial ecosystem restructuring, thereby ensuring sustainable economic benefits and long-term cultural impact.

Globally, theories of industrial heritage conservation and transformation have evolved from a focus on physical preservation to a multidimensional, integrated approach. Early efforts were centered on material conservation, followed by the incorporation of cultural landscape theory, adaptive reuse strategies, and community participation. More recently, industrial heritage transformation has expanded towards urban regeneration, green development, and the creative economy. In the future, interdisciplinary integration, social engagement, and sustainability will play an even greater role in ensuring the long-term preservation and innovative reuse of industrial heritage.

2.2 Localization Characteristics of Italy's Industrial Heritage Transformation Strategies

As a country rich in cultural heritage, Italy has adopted a distinctive approach to industrial heritage conservation and adaptive reuse, drawing from international experiences while emphasizing its own local characteristics. Compared to other Western European nations, Italy's industrialization process was relatively late, resulting in a diverse range of industrial heritage types—from the factories and mines of the developed northern industrial regions to the small-scale artisanal workshops in central and southern Italy. In recent years, Italy has progressively incorporated industrial heritage into its cultural heritage legislation and management system, emphasizing cultural identity, functional innovation, and multi-stakeholder governance in conservation and revitalization efforts. Italy's industrial heritage protection and transformation practices offer valuable insights on a global scale, as they integrate historical and cultural values with local economic, social, and environmental needs, resulting in a unique industrial heritage conservation and adaptive reuse system.

2.2.1 Balancing Cultural Identity and Historical Conservation

Italy's industrial heritage conservation strategy is deeply rooted in its long-standing cultural heritage management system, sharing principles with traditional architectural and archaeological heritage protection. As a pioneer in European cultural heritage conservation, Italy places a strong emphasis on cultural identity in its industrial heritage conservation and adaptive reuse practices. Industrial heritage is regarded as a witness to the country's industrial development and is closely linked to local history, social memory, and collective identity. Consequently, Italy's conservation strategies focus not only on the physical restoration and reuse of industrial spaces but also on preserving their cultural significance and symbolic value to enhance social recognition, local cultural pride, and sustainable development.

（1） Industrial Heritage Conservation within the Cultural Heritage Framework

Since the mid-to-late 20th century, Italy has gradually incorporated industrial heritage into its national cultural heritage protection system, granting it the same legal status as traditional historical buildings and archaeological sites. While Italy's cultural heritage protection laws—such as the 2004 Code of Cultural Heritage and Landscape—were initially designed for classical heritage, they have since been expanded to include significant industrial heritage sites.

In 1985, the Italian government enacted the Legge Galasso (Galasso Law), which formally recognized industrial heritage as part of the national cultural heritage, laying the foundation for its legal protection. The introduction of this law marked a shift in perception—industrial heritage was no longer viewed as merely obsolete infrastructure from the industrialization process but rather as assets with historical, technological, and socio-cultural value.

Following this, the Italian Ministry of Culture (MiC) has continuously refined laws and regulations to further systematize industrial heritage protection. For example, the government initiated the creation of a National Industrial Heritage Register, systematically cataloging and assessing industrial heritage resources across the country. This provides a scientific basis for the conservation, restoration, and reuse of industrial heritage at various levels. Additionally, Italy encourages cooperation between local governments, enterprises, cultural institutions, and academic research organizations to promote industrial heritage protection, research, and revitalization.

Theoretically, Italian scholars have introduced the concept of "Patrimonialization", which refers to the process of transforming industrial sites and practices into recognized cultural heritage[7]. This transformation is often driven by identity recognition and serves as a means for local communities to construct shared memory. However, some studies highlight the persistence of "Authorized Heritage Discourse" in Italy’s traditional heritage narratives, where officials and experts determine the value of heritage, while local communities play a passive role. This tendency prioritizes the material aspects of heritage while overlooking its intangible dimensions.

To address this issue, Italy has begun to reflect on and adjust its approach, emphasizing that industrial heritage conservation should go beyond structural restoration to actively empower communities by raising awareness of industrial history. For instance, in the conservation of Milan’s old factory sites, efforts extended beyond preserving the factory buildings to include the collection of worker interviews, artisanal techniques, and historical records, enriching the social and cultural dimensions of heritage. Overall, Italy’s approach seeks to achieve a "dual objective": ensuring the physical integrity of industrial heritage while fostering public recognition and community engagement, integrating it as part of local culture.

（2）Integration of Industrial Heritage with Local Culture

Italy places significant emphasis on integrating industrial heritage into local narratives, presenting it as an integral chapter of regional culture. Many industrial sites have been repurposed into museums or cultural centers, directly telling the story of local industrial history.

For example, Crespi d’Adda, a 19th-century industrial utopian workers' village in

Lombardy, was inscribed as a UNESCO World Heritage Site in 1995, illustrating the impact of industrialization on community life. Similarly, Ivrea, a planned industrial city in the Piedmont region, developed around Olivetti's typewriter factory and was inscribed on the World Heritage List in 2018 for its unique 20th-century industrial urban planning and social welfare system[8]. The Ivrea heritage area includes factories, office buildings, and community facilities built between the 1930s and 1960s, now repurposed for various cultural activities. This case exemplifies deep integration between industrial heritage and local culture, demonstrating that factories shape not only economic output but also urban form and intangible identity.

Another notable case is the Arsenale di Venezia (Venetian Arsenal), one of Europe's oldest shipyards, dating back to the 12th century. Originally the naval shipbuilding hub of the Venetian Republic, it lost its industrial function with the decline of the shipbuilding industry. However, in the 21st century, under urban renewal and cultural heritage policies, the Venetian Arsenal was revitalized as a multipurpose venue for culture, research, and international exhibitions.

Figure 2.5 The Venice Arsenal Redeveloped as a Multifunctional Venue

Image Source: SM Ingegneria Official Website

Italy's industrial heritage transformation consistently prioritizes cultural identity, ensuring that heritage value extends beyond spatial preservation to encompass historical continuity and social function. Through exhibitions, educational initiatives, and public engagement, Italy actively fosters local awareness and appreciation of industrial heritage, making it a vehicle for community memory and pride. For instance, many regions host annual "Industrial Heritage Days", inviting former workers to share stories, organizing industrial archaeology tours, and increasing public understanding of local industrial culture.

In practice, Italy's industrial heritage projects embody the concept of "genius loci" (spirit of place)—ensuring that industrial heritage retains its historical essence and cultural significance while serving contemporary local needs. This "localized" approach to conservation allows industrial heritage to "tell local stories and serve local communities," achieving a balanced cultural identity and historical protection strategy.

2.2.2 Diversification of Adaptive Reuse Strategies

Unlike traditional heritage conservation models that emphasize authenticity and static preservation, Italy's industrial heritage transformation places greater emphasis on adaptive reuse. This approach retains the fundamental architectural structure while reallocating functions and repurposing spaces, allowing industrial heritage to be reintegrated into modern society and the economic system. Such a strategy not only helps preserve the historical value of industrial heritage but also stimulates regional economies, promotes sustainable development, and enhances social inclusivity. In Italy, adaptive reuse has become a key strategy in industrial heritage conservation, manifesting in diverse trends, including cultural and creative industry development, sustainable ecological transformation, and mixed-use redevelopment.

（1）Cultural and Creative Industry-Oriented Reuse

利 One of Italy's most distinctive industrial heritage strategies is the conversion of abandoned industrial buildings into cultural and creative industry hubs. Many former factories have been transformed into museums, art centers, and design innovation parks, preserving the aesthetic uniqueness of industrial architecture while providing distinctive spaces for creative activities. Historically, heritage buildings have proven to attract creative professionals, making them ideal incubators for the creative economy.

A prime example is Manifattura Tabacchi in Florence, a former tobacco manufacturing plant built in the 1930s, which became a core site of Italy's tobacco industry by the mid-20th century. However, as the industry declined, the plant was shut down in 2001, leaving the site vacant for years. In recent years, under the guidance of adaptive reuse strategies, the site has been transformed into a cultural complex integrating arts, design, education, and creative industries.

Other notable examples include OGR in Turin, a former locomotive repair factory, now converted into a contemporary arts and technology innovation center, and Ansaldo

Factory in Milan, which has been repurposed into a design museum and fashion arts center. These projects breathe new cultural vitality into traditional industrial cities, supporting creative industries and tourism.

A key feature of Italy's cultural reuse projects is the emphasis on maintaining the authenticity and atmosphere of industrial heritage sites. Through lighting design, exhibition planning, and spatial interpretation, industrial elements are transformed into artistic features, enhancing their attractiveness to creative professionals. In summary, culture and creative industry-driven reuse has revitalized Italy's industrial heritage, achieving a dual goal of cultural value creation and economic productivity.

（2）Sustainability and Ecological Transformation

In response to the severe pollution and environmental degradation affecting many industrial sites, Italy has incorporated ecological transformation concepts into industrial heritage regeneration, combining environmental restoration with functional renewal. With the increasing global focus on environmental protection and carbon neutrality, industrial heritage reuse in Italy now integrates green building technologies, low-carbon design, and ecological infrastructure, aiming to reduce environmental impact and enhance urban ecological quality. Some cities have converted former industrial sites into ecological parks or green spaces, simultaneously improving urban livability and introducing a new form of heritage conservation.

For instance, Parco della Colletta in Turin was once a wasteland of abandoned factories and polluted soil, formerly serving as a hub for steel and machinery industries. Following the decline of industry, the area became symbolic of urban decay. However, through large-scale ecological restoration and adaptive reuse, it has been transformed into a green urban park.

Italy's industrial heritage projects increasingly incorporate green goals, such as solar energy systems, rain gardens, and environmental education facilities. These eco-transformation strategies enrich the adaptive reuse dimension, ensuring that projects are not only culturally and economically viable but also environmentally beneficial. Through ecological design, former "environmental liabilities" have been converted into urban green lungs and scenic corridors, exemplifying the synergy between heritage protection and sustainable urban development.

（3）Introduction of Mixed-Use Spaces

Italy's industrial heritage transformation often adopts mixed-use development models to accommodate diverse societal needs. The single-function industrial zones of the past no longer align with the demands of modern cities, prompting many adaptive reuse projects to integrate office spaces, commercial areas, residential units, educational institutions, and cultural facilities into one cohesive environment. This multi-functional approach enhances site vitality and ensures long-term sustainability.

On one hand, mixed-use development meets the needs of various communities, encouraging continuous engagement throughout the day. On the other hand, diverse revenue streams contribute to the economic sustainability of heritage projects. Many Italian industrial heritage sites now embrace this model, including Milan’s "Industry 4.0" Innovation Hub, which transformed an old factory into a multi-use complex featuring startup incubators, museums, and cafes, and Genoa’s Cotton Warehouse Revitalization, which integrates a shopping mall, aquarium, and historical exhibition spaces.

Italian planners argue that single-use transformations (e.g., purely museum-oriented reuse) may struggle with long-term viability. In contrast, multi-functional spaces maximize spatial utilization and public engagement. However, successful mixed-use projects require careful planning, ensuring that functions complement rather than compete with each other. For example, functional adjacency, time-based use variations, and synergies between different spaces can create a 1+1>2 effect.

A notable case is the Pietrarsa Railway Factory in Naples, one of Italy’s earliest train manufacturing plants, built in the 1840s. Once a symbol of Italian railway industry, the factory ceased operations in 1975. To prevent abandonment, the Naples municipal government redeveloped the site into a multi-functional urban cultural center.

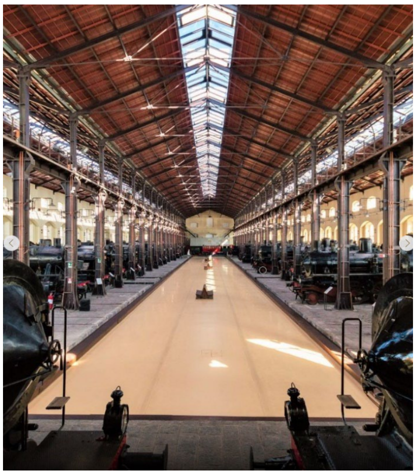


Figure 2.6 Pietrarsa Cultural Center as a Museum

Image Source: FS Italian Foundation Official Website

From an operational perspective, mixed-use developments have brought new vitality to Italian industrial heritage, ensuring 24-hour site engagement and making them dynamic urban spaces. Ultimately, multi-functional reuse has become a defining feature of Italy's industrial heritage transformation, maximizing site potential while respecting historical values.

2.2.3 Collaborative Operation of Multi-Level Governance Models

The transformation of industrial heritage in Italy involves a multi-level governance system, encompassing national and local governments, non-governmental organizations (NGOs), and private sector collaboration. This governance model ensures the sustainability, social inclusivity, and economic vitality of industrial heritage projects through close cooperation among diverse stakeholders. Within this framework, government policies, private capital, social organizations, and community participation are interwoven, collectively driving the transformation and reuse of industrial heritage.

（1）Government Policy Guidance and Legal Support

The Italian government plays a crucial role in guiding industrial heritage transformation by formulating legal frameworks, financial incentives, and long-term planning to provide a strong policy foundation for industrial heritage conservation and reuse.

At the national level, the Italian government has established the National Industrial Heritage Fund, which provides financial support for industrial heritage projects that hold historical, cultural, and social value. This fund primarily assists projects located in urban regeneration areas or economically underdeveloped regions, supporting their restoration and adaptive reuse. Additionally, the government encourages private enterprises, investors, and NGOs to participate in industrial heritage projects through tax reductions, subsidies, and low-interest loans. These policies enhance the financial viability of projects while attracting broader social engagement in industrial heritage transformation. For example, tax incentives for heavy industry zones create a more favorable investment environment, attracting greater private sector participation.

At the local level, industrial heritage reuse has been integrated into urban planning and development strategies. Cities such as Milan and Turin have introduced planning regulations requiring the preservation of valuable industrial buildings during redevelopment. Additionally, municipal policies allocate land use for cultural and public purposes to ensure that industrial heritage contributes to urban renewal. As one planning directive states, "Heritage conservation should be a primary goal in urban planning, not an afterthought." Local governments are therefore responsible for embedding industrial heritage conservation and adaptive reuse within overall city planning, promoting a strategy of "innovation through preservation."

Italy employs a hierarchical governance system where national, regional, and municipal governments each play a distinct role: The national government provides legal frameworks and funding mechanisms. Regional governments coordinate project approvals and technical guidance. Municipal authorities oversee implementation and management. This multi-tiered collaboration ensures that macro-level policies are effectively implemented at the project level. For example, in the regeneration of the former ILVA steel plant in Naples, the national government provided environmental remediation funds, the Campania regional government coordinated redevelopment planning, and the municipal government executed on-site transformation and management. This case highlights how a well-structured policy and regulatory framework plays a pivotal role in ensuring the successful transformation of industrial heritage, with government guidance and coordination serving as an indispensable pillar of the Italian model.

（2）Active Participation of Private Capital and Social Organizations

Private enterprises and social organizations play a crucial role in industrial heritage transformation in Italy. Given the high investment costs and long development cycles associated with large-scale heritage projects, relying solely on government funding is often unsustainable. As a result, public-private partnerships (PPP) have emerged as a key financing model, where the government provides heritage resources and policy support, while private enterprises contribute funding and manage redevelopment under long-term operational agreements.

A notable example is the Lingotto Factory in Turin, where Fiat collaborated with the local government to redevelop the former car manufacturing plant. As the owner of the industrial site, Fiat directly invested in the redevelopment, ensuring efficient implementation and commercial viability.

Beyond private enterprises, various social organizations are also actively involved in industrial heritage conservation. The Italian Association for Industrial Archaeological Heritage (AIPAI), established in 1997, has played a leading role in advocating for industrial heritage protection. Similarly, the Italian Environmental Fund (FAI), a non-profit organization, has launched public campaigns to preserve abandoned industrial sites, including public voting initiatives to identify significant industrial heritage sites for restoration funding.

However, social organizations also face challenges—for instance, some FAI projects struggled with sustainable funding and visitor engagement, leading to difficulties in maintaining long-term site operations. To address these issues, Italy has explored diversified funding and operational models, such as: Hosting cultural markets and industrial heritage festivals to increase site visibility and attract private sponsorships. Offering tax incentives to encourage private sector investment in heritage projects.

Overall, Italy's industrial heritage transformation follows a "government + market + society" model, where the government provides policy oversight, while enterprises and social organizations contribute financial and creative resources, ensuring multi-stakeholder collaboration and shared success.

（3）Community Engagement and Local Co-Governance

Community participation is a key factor in Italy's industrial heritage transformation. Local residents, cultural groups, and academic institutions are not only involved in heritage conservation but also actively contribute to planning and management decisions. Italy's experience demonstrates that genuine community involvement is essential for ensuring the long-term sustainability and social acceptance of industrial heritage projects.

Several Italian cities have established public consultation committees for heritage reuse projects, engaging community representatives, former factory workers, and cultural experts in decision-making discussions. This approach has been particularly evident in the management of Ivrea, a UNESCO World Heritage Site.

Studies on Ivrea's heritage management revealed that local residents initially had limited awareness of redevelopment plans, highlighting the need for more inclusive participatory governance. In response, the Ivrea municipal government adopted an action research approach, organizing workshops where students and residents collaboratively envisioned the future of the heritage site. These initiatives empowered stakeholders—especially younger generations—to contribute creative ideas, leading to enhanced public engagement and innovative proposals.

Italy's community-based governance model ensures that industrial heritage projects align with local needs and cultural identities, preventing top-down decision-making from alienating communities. However, further improvements are needed, such as: Enhancing public awareness of project details. Creating more accessible participation channels.

Some scholars advocate adopting deliberative democracy models, incorporating public discussions and feedback mechanisms at every stage of a project. Additionally, tools like social network analysis can be used to map stakeholder relationships and optimize governance structures. Ultimately, community co-governance ensures that residents are not just passive beneficiaries but active contributors to heritage value assessment and reuse strategies.

2.3 Systematic Exploration of Industrial Heritage Assessment Methods

2.3.1 Representative Assessment Methods and Tools

The assessment system for industrial heritage serves as a core component of heritage conservation, redevelopment, and reuse decision-making. Its evolution reflects the development of heritage conservation theories and the increasing integration of modern technological tools. From early single-dimensional evaluation methods focusing on historical and cultural value, the field has progressed to comprehensive multi-dimensional assessment systems that incorporate spatial characteristics, functional adaptability, and ecological sustainability. Scholars and practitioners have developed various assessment models and tools to address the complex and dynamic attributes of industrial heritage.

Table 2.4 Comparison of Typical Evaluation Methods and Tools for Industrial Heritage

Evaluation Tool / Method	Core Content	Advantages	Limitations
Multi-dimensional Value Assessment	Constructs a value matrix by integrating historical, artistic, social, technological, and environmental dimensions.	Comprehensive and holistic; supports both qualitative and quantitative analysis	Lacks standardized metrics; limited cross-project comparability
AHP and Fuzzy Comprehensive Evaluation	AHP determines weights; fuzzy logic addresses subjective uncertainty; often used in combination.	Clear structure; enhances quantification and result stability	Complex calculations; heavily reliant on expert judgment

Geographic Information System (GIS)	Visualizes and analyzes spatial distribution, accessibility, and environmental data; can integrate with AHP.	Suitable for large-scale spatial analysis; intuitive visualization	Cannot independently reflect cultural value; needs to be used with supplementary models
Historic Building Information Modeling (HBIM)	3D modeling based on BIM to document structural, material, and historical evolution data	High-precision modeling; ideal for structurally complex heritage	High modeling cost; requires extensive data input
Historic Urban Landscape (HUL) Approach	Emphasizes integration of cultural context and heritage into broader urban landscapes	Highlights holistic and sustainable perspectives; suitable for urban regeneration	Relatively weak operability; often requires combination with other tools

Source: Compiled by the author

（1）Multi-Dimensional Value Assessment Method

Industrial heritage possesses multi-dimensional value, requiring an evaluation framework that considers its historical, artistic, social, technological, and environmental significance.

Early assessments primarily employed qualitative methods, where experts subjectively evaluated industrial heritage based on historical-cultural significance. These early frameworks were influenced by international heritage conventions such as the Venice Charter and the Nara Document on Authenticity, which emphasized the principles of authenticity, integrity, and sustainability in cultural heritage preservation. Additionally, TICCIH's Nizhny Tagil Charter explicitly recognized the historical, technological, social, architectural, and scientific value of industrial heritage.

More recently, scholars have attempted to refine value assessment models by integrating both qualitative and quantitative methods. Some researchers have developed a standardized matrix for assessing urban industrial heritage, expanding the evaluation dimensions to eight key categories: historical value, artistic value, social value, cultural value, technological value, economic value, environmental value, functional adaptability.

This expanded matrix enhances the depth of industrial heritage assessment, incorporating economic contribution, environmental impact, and functional adaptability to provide a more holistic evaluation. For example, in the case of the Mawei Shipyard Heritage Site in Fuzhou, researchers applied the AHP model to assess the heritage's value across multiple dimensions[9]. Their findings indicated distinct value compositions for different types of industrial heritage, allowing them to develop tailored conservation and reuse strategies.

Figure 2.7 Aircraft Assembly Workshop at the Tiexie Plant, a Remnant of the Fuzhou Chuanzheng Industrial Heritage

Source: Fujian Chuanzheng

In China, Luo Chao and Wang Duo have explored a multi-dimensional urban value-based evaluation system for industrial heritage, using Suzhou as a case study[10]. Similarly, Chen Zhao-Qian analyzed the cultural memory aspect of industrial heritage through a case study on Wuxi's Canal Bund, highlighting the importance of intangible values[11]. Internationally, Francesca et al. proposed a multi-criteria evaluation framework for assessing adaptive reuse strategies for industrial heritage, applying it to the Italian Steel Industry[12].

While the multi-dimensional value assessment system provides a comprehensive framework, its primary limitation lies in the lack of standardized evaluation criteria across different dimensions, making comparisons between projects difficult. To address this, researchers are integrating mathematical models for weight assignment and quantitative scoring. For instance, Gao Fei's study applied Structural Equation Modeling (SEM) to evaluate the value of Middle East Railway industrial heritage, emphasizing the importance of industrial heritage corridors[13].

（2）Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE)

A major challenge in multi-criteria assessments is quantifying each dimension and integrating the results into a comprehensive evaluation. To overcome this, AHP (Analytic Hierarchy Process) and Fuzzy Comprehensive Evaluation (FCE) have emerged as valuable analytical tools in industrial heritage assessment.

AHP, as a structured decision-making model, has been widely applied in the assessment of industrial heritage. This method decomposes complex evaluation criteria into a hierarchical structure, assigning weights to each factor through expert scoring and consistency checks. For instance, in the case of the Mawei Shipyard, researchers constructed an AHP model comprising eight primary evaluation dimensions, with experts assigning relative weights to each category, ultimately forming a quantified assessment model. This approach allows for a more systematic and logical evaluation, ensuring that key heritage values are adequately considered and prioritized.

However, the reliance on expert judgment in AHP introduces a degree of subjectivity, which is where Fuzzy Comprehensive Evaluation (FCE) becomes particularly useful. FCE is designed to address uncertainties in expert judgment by applying fuzzy mathematics, thereby converting qualitative assessments into quantitative measures. This makes it especially effective for handling complex, uncertain, or imprecise data, characteristics that are common in industrial heritage evaluations. The advantage of FCE lies in its ability to handle ambiguity and subjectivity in assessment, thereby providing a more refined and systematic evaluation framework.

In practice, AHP and FCE are often combined to enhance evaluation reliability. AHP first determines the weight of each factor, establishing a structured foundation, while FCE then assigns a final evaluation score, incorporating the uncertainty and subjectivity of expert opinions into a quantifiable measure. This combined AHP-FCE approach has been successfully applied to various industrial heritage evaluation projects. Chen Yang et al. utilized AHP-FCE to assess the industrial heritage value of Suzhou’s Musical Instrument Factory, providing decision-making support for its conservation and adaptive reuse strategies[14]. Similarly, Li Haoying and Li Ming applied the AHP-FCE framework to evaluate the architectural value of the Jilin Machine Bureau Site, demonstrating how this method can systematically assess the significance of industrial heritage sites[15].

Despite its advantages, AHP still relies heavily on expert judgment, which inherently carries an element of subjectivity. In contrast, FCE enhances this process by mathematically modeling uncertainty, thus improving assessment accuracy. The integration of AHP and FCE has now become a widely adopted standard approach in industrial heritage assessment, significantly enhancing the objectivity, consistency, and applicability of evaluation results. As industrial heritage projects continue to diversify in scope and complexity, this combined approach offers a scientifically rigorous method for guiding conservation, restoration, and adaptive reuse strategies.

（3）Geographic Information Systems (GIS)

Beyond evaluation models based on indicator systems, spatial analysis methods are becoming increasingly important in the assessment of industrial heritage. Among these, Geographic Information Systems (GIS) have emerged as an indispensable technological tool. GIS enables systematic analysis of industrial heritage sites, considering their geographical location, spatial distribution, accessibility, and surrounding land use. This scientific approach supports heritage conservation and redevelopment planning, allowing for more precise and data-driven decision-making.

For large-scale industrial heritage surveys, GIS can be used to record and visualize the spatial distribution of heritage sites, illustrating their relationship with urban structures and surrounding environmental factors. This provides a macro-level perspective that aids in evaluating heritage value and informing conservation planning. Furthermore, GIS can be integrated with multi-criteria assessment methods to support spatial decision-making for specific projects. For instance, a study on the former industrial zone in Algiers, Algeria, introduced a GIS-AHP method to assess the reuse potential of industrial buildings[16]. Researchers such as Bouaziz et al. employed weighted overlay analysis in ArcGIS, spatially mapping factors such as historical significance and building conditions to classify priority sites for conservation or redevelopment. The results provided decision-makers with an intuitive, map-based visualization of heritage values, highlighting sites that required immediate intervention. This approach underscores the advantage of GIS in heritage assessment, effectively transforming maps into analytical tools that guide conservation strategies.

In recent years, scholars have applied GIS technology to industrial heritage research for various purposes, including hotspot distribution analysis, accessibility assessments, and land value evaluations. In Italy, GIS has been employed in industrial heritage surveys and valuation efforts, with regions such as Lombardy developing a GIS-based industrial heritage database. This system geographically visualizes historical, architectural, and legal information related to heritage sites, aiding in regional-scale assessments and the design of heritage tourism routes. As GIS technology continues to advance, it is likely to incorporate more complex analyses—such as accessibility studies, viewshed analysis, and spatial integration with landscape features—further enriching the dimensions of industrial heritage assessment.

The introduction of GIS technology has provided a powerful tool for industrial heritage research, enabling scholars to conduct multi-scale spatial analyses and data-driven management. For example, Xiaoli Fan et al. utilized GIS to analyze the spatial distribution and influencing factors of industrial heritage in Italy, revealing how regional development levels and policy support affect heritage site distributions[17]. Similarly, Trepal and Don proposed a historical sequence GIS analysis method, using GIS to map and analyze the spatial distribution and historical evolution of industrial heritage[18]. Another study by John et al. combined GIS technology with CityEngine software to create a data-driven 3D model, illustrating the temporal changes in industrial heritage landscapes[19].

Despite its strengths, GIS technology primarily relies on existing spatial datasets, making it less effective in directly quantifying the cultural value of industrial heritage. As a result, GIS is typically integrated with other evaluation frameworks to achieve a more comprehensive assessment. For instance, Chen Ru et al. combined GIS with AHP to develop a landscape evaluation index system, providing a scientific methodological approach for assessing the landscape value of industrial heritage[20].

Overall, GIS has revolutionized the way industrial heritage is assessed and managed, offering a spatially integrated and visually dynamic approach. As GIS-based tools continue to evolve, they will play an increasingly crucial role in industrial heritage conservation, spatial planning, and adaptive reuse strategies.

（4）Historic Building Information Modeling (HBIM)

With the advancement of digital technology, Historic Building Information Modeling (HBIM) has emerged as an innovative tool for industrial heritage assessment and conservation planning. HBIM is an extension of Building Information Modeling (BIM), specifically designed for heritage conservation. It enables precise 3D digital modeling, systematically recording and managing the architectural structure, material composition, historical restoration records, and structural deterioration of industrial heritage sites. By integrating these elements into a comprehensive digital framework, HBIM provides accurate data support for restoration and adaptive reuse projects.

For industrial heritage, HBIM is particularly valuable due to the complex structures and extensive mechanical systems often found in industrial buildings. Traditional 2D architectural drawings struggle to fully represent these intricate elements, making HBIM a superior solution for capturing both geometric and attribute-based information. Through HBIM, a "digital twin" of the heritage site can be created, offering a highly detailed model that allows for precise management and analysis.

The concept of "temporal HBIM", proposed by Currà et al., illustrates the potential of HBIM in tracking the evolution and production processes of industrial heritage[21]. Their research focused on the Segnè Paper Mill in Tivoli, constructing an HBIM model of the factory and its associated heritage structures. By incorporating different historical phases of architectural elements and machinery, the study enabled an in-depth analysis of building transformations and industrial workflows. The findings demonstrated that HBIM can significantly enhance heritage recognition and understanding, providing a visually immersive representation of factory layouts and machinery configurations. This approach aids experts in heritage value assessments, conservation strategies, and adaptive reuse planning.

The study also highlights the key advantages of HBIM, particularly in industrial heritage conservation and restoration. By integrating precise geometric and material data, HBIM enhances the accuracy and efficiency of conservation efforts. However, one of its major challenges lies in the complexity and high cost of data acquisition and modeling, making it less feasible for large-scale industrial heritage assessments at this stage. The labor-intensive nature of HBIM, including historical data collection, 3D scanning, and model refinement, means that its full implementation still requires further technological and methodological advancements.

In the broader field of historic building conservation, HBIM has been effectively utilized to support structural analysis, restoration planning, and digital documentation. Nieto et al. explored how structural deformation analysis can be integrated into HBIM models to enhance accuracy and reliability in conservation efforts. Their study, focused on the Pavilion of Charles V’s Palace in Seville, Spain, demonstrated the transition from traditional surveying techniques to advanced digital methodologies. The research underscored HBIM’s potential to improve conservation quality while also highlighting practical challenges, such as data accuracy, model updates, and interdisciplinary collaboration.

HBIM has already been applied in industrial heritage conservation in Italy. For instance, the HBIM modeling of the Naples Refinery Storage Tanks has facilitated assessments of structural stability and reuse potential. Additionally, researchers at Politecnico di Milano have developed an industrial heritage component library, aimed at accelerating the HBIM modeling process for historic factory structures. The advantage of HBIM extends beyond recording existing conditions—it also enables the simulation of renovation scenarios, allowing planners to assess the impact of modifications on historical structures and visualize adaptive reuse options.

Despite still being in its early stages of adoption, HBIM is increasingly recognized as a powerful tool for the future of heritage assessment and management. Its ability to bridge technology and cultural preservation makes it an essential innovation for enhancing precision, efficiency, and sustainability in industrial heritage conservation. As digital heritage technologies continue to evolve, HBIM is expected to play a crucial role in the documentation, restoration, and adaptive reuse of industrial heritage sites, setting new standards for data-driven and interdisciplinary conservation practices.

（5）Historic Urban Landscape (HUL)

In addition to specific evaluation models, recent heritage conservation theories have shifted from individual building assessments to broader urban heritage management frameworks. Among these, the Historic Urban Landscape (HUL) approach has emerged as a key theoretical tool in international heritage conservation. HUL emphasizes that heritage conservation should be integrated into the overall urban environment, historical development, and socio-cultural context, rather than assessing buildings in isolation. This approach has been widely applied in industrial heritage regeneration projects, as it provides a more holistic and adaptive perspective.

The HUL approach recognizes that industrial heritage sites are often deeply embedded in the urban fabric, influencing the spatial structure, economic activities, and collective memory of local communities. By considering historical layers and urban dynamics, this method aims to balance heritage preservation, urban development, and sustainability. For example, Tao Shengqi et al. conducted a detailed study on the industrial heritage of Shizuishan, integrating HUL principles to propose renewal strategies[22]. Their research aimed to protect industrial heritage while promoting sustainable urban development, demonstrating the applicability of HUL in shaping adaptive conservation policies. Additionally, Zhou Yanbin's study on Nanjing Pukou Railway Station applied the HUL approach to evaluate and optimize the protection and development of railway industrial heritage, further illustrating the practical value of this perspective[23].

Overall, the evaluation models and tools for industrial heritage have evolved from single-dimensional to multi-dimensional assessments, from qualitative to quantitative methods, from static to dynamic approaches, and from individual building analysis to city-wide strategies. While multi-dimensional value assessment frameworks offer comprehensive evaluation structures, they often lack quantitative precision. Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) enhance scientific rigor in assessments, but remain dependent on expert judgment. Geographic Information Systems (GIS) and Historic Building Information Modeling (HBIM) improve spatial analysis capabilities, yet still require integration with other models for a more comprehensive assessment. In contrast, the HUL approach situates industrial heritage within a broader urban development context, making evaluations more aligned with city-wide planning needs.

As research and practice in industrial heritage conservation continue to evolve, the key challenge lies in integrating multiple assessment models and tools to develop a more precise, systematic, and adaptable evaluation framework. The future of heritage conservation and adaptive reuse will depend on interdisciplinary collaboration, technological advancements, and dynamic policy frameworks to ensure that industrial heritage remains a valuable asset for sustainable urban transformation.

2.3.2 Construction of a Multidisciplinary Cross-Evaluation Model

The evaluation of industrial heritage transformation encompasses multiple dimensions, including economic benefits, social impact, cultural value, and environmental sustainability. Due to the complexity and interconnectedness of these factors, a single-discipline approach often fails to provide a comprehensive assessment. Consequently, scholars have increasingly explored multidisciplinary cross-evaluation models to establish a more systematic and scientific framework for industrial heritage assessment.

Table 2.5 Comparison of Interdisciplinary Evaluation Models for Industrial Heritage

Model / Method	Core Content	Advantages	Limitations
Socio-economic Evaluation Model	Assesses indicators such as economic output, employment, and social welfare; often uses SIA, DCE, MCA.	Quantifies economic benefits; enhances social support; addresses multiple stakeholders' interests	Overlooks cultural/intangible values; some indicators are highly subjective
Environmental Sustainability Analysis	Focuses on carbon footprint, energy consumption, pollution control, and ecological restoration; uses tools like LCA, EFA, and green building certifications.	Provides quantitative support for environmental goals; aligns with green policy frameworks	Difficult data acquisition; limited coverage of cultural and social dimensions
Cultural and Community Impact Assessment	Evaluates cultural continuity, sense of identity, and community integration using methods such as CVA, public participation, and SIA.	Emphasizes humanistic concerns; fosters community engagement; integrates local cultural context	Difficult to quantify; requires long-term monitoring; integration of stakeholder feedback is complex
Integrated Assessment Framework (Interdisciplinary)	Combines qualitative and quantitative indicators; builds dashboards or adopts MCDM, PESTLE, DPSIR frameworks.	Comprehensive structure; strong interdisciplinary integration; adaptable to complex contexts	Complex weighting and data integration; high operational threshold

Source: Compiled by the author

（1）Evaluation Model from a Socio-Economic Perspective

The adaptive reuse of industrial heritage is often expected to drive economic development and enhance social well-being. Therefore, evaluating the effectiveness of such projects from a socio-economic perspective is essential. The key evaluation criteria include direct economic output (such as tourism revenue and job creation) and indirect social benefits (such as enhanced community cohesion and educational improvements). Han et al. adopted a sustainable development framework, incorporating economic, social, and environmental dimensions into the evaluation of industrial heritage projects[24]. Similarly, de Broekert et al., in their study on post-industrial cities in the Netherlands, applied a "three-pillar" analysis to examine the economic growth, social well-being, and environmental improvements generated by industrial heritage projects. Their findings indicated that successful industrial heritage regeneration can simultaneously create jobs, improve community life, and enhance the environment.

Economic value assessment plays a critical role in determining the feasibility of industrial heritage conservation and reuse. Several methodologies have been adopted to quantify these effects. Bertacchini Enrico et al. applied a Discrete Choice Experiment (DCE) method to evaluate the economic value of the Baosteel Industrial Zone in Shanghai. By conducting survey-based studies, they assessed public preferences for different attributes of the industrial site, including historical landmarks and intangible cultural heritage[25]. Chen Jiamin applied Travel Cost Method (TCM) and Contingent Valuation Method (CVM) to assess the cultural capital of Beijing's 798 Art District[26]. These approaches not only measured the use and non-use values of the site but also provided data-driven recommendations for its future management and development.

Beyond economic valuation, Social Impact Assessment (SIA) models have been employed to measure public satisfaction and community recognition regarding industrial heritage reuse. For instance, Meng et al. conducted a public satisfaction survey across eight repurposed industrial sites in Beijing to evaluate the quality of spatial reuse[27]. These socio-economic models emphasize a human-centered approach, treating industrial heritage as part of a broader socio-economic system. By integrating both qualitative and quantitative methodologies, these models assess the impact of industrial heritage transformation on employment, income levels, and social capital. For policymakers, such assessments provide measurable indicators beyond cultural value, strengthening the case for allocating public resources to industrial heritage projects.

Despite their strengths, these economic evaluation models tend to underrepresent cultural and social dimensions, making it difficult to fully capture the intangible value of industrial heritage. To address this limitation, scholars have introduced Social Network Analysis (SNA) to assess the synergistic interactions among stakeholders in industrial heritage projects. For example, Song Jinghua et al. applied SNA to examine the repurposing of the Sanlin Bridge factory into a community center[28]. Their study analyzed spatial utilization and the redistribution of social capital, highlighting the restructuring of industrial networks, collaboration between businesses, and the clustering effect of cultural tourism industries. This network-based approach complements traditional economic evaluations by incorporating social dynamics and stakeholder interactions, offering a more holistic perspective on industrial heritage transformation.

（2）Environmental Sustainability Analysis in Industrial Heritage Transformation

The transformation of industrial heritage often involves land remediation, energy retrofitting, carbon emission control, and pollution management, making sustainability assessment a crucial area of research. Environmental sustainability analysis evaluates the performance of industrial heritage projects in energy conservation, carbon reduction, pollution control, and ecological restoration. Current studies in this field focus on methodologies such as Life Cycle Assessment (LCA), Ecological Footprint Analysis (EFA), and Green Building Certification Systems (e.g., LEED and BREEAM). These approaches provide quantitative insights into the environmental benefits of adaptive reuse versus demolition and new construction, reinforcing the argument that reuse is a more eco-friendly and resource-efficient alternative.

A significant strand of research compares carbon emissions between direct renovations and demolition-based redevelopment, using carbon footprint and LCA to measure energy consumption and emissions before and after reuse projects. For instance, studies have demonstrated that industrial heritage renovation leads to lower carbon emissions than new construction by reducing the embodied energy loss in demolition and new material production. Some scholars have developed indicator systems to assess sustainability benefits. Camoletto et al. designed a multi-dimensional indicator system to quantify the environmental, social, and economic benefits of industrial heritage reuse. Their model incorporated energy efficiency, land regeneration levels, and green coverage ratios to create a composite sustainability index, enabling a comprehensive assessment of a project's environmental contributions. By measuring factors such as soil remediation area, groundwater quality improvements, and biodiversity enhancement, these models provide clear evidence of environmental gains. Furthermore, if certain sustainability targets are not met, design adjustments—such as adding green infrastructure or improving waste management—can be implemented in response.

Life Cycle Assessment (LCA) has become a widely used quantitative tool for evaluating the long-term environmental impact of industrial heritage buildings. For example, Wang Xin conducted a lifecycle environmental impact and cost analysis of industrial buildings in Tianjin's central districts, offering data-driven insights for conservation and adaptive reuse strategies[29]. Similarly, Long Yanru's research applied lifecycle management theories to propose systematic management frameworks aimed at promoting the sustainable utilization of industrial heritage[30]. Meanwhile, Ecological Footprint Analysis (EFA) has been employed to measure land use intensity and water resource consumption, providing a direct measure of sustainability in industrial heritage reuse. Zhang Guangmin applied carbon footprint analysis to assess and predict carbon emissions in old industrial district regeneration, offering scientific carbon reduction strategies for heritage conservation efforts[31].

Energy retrofitting and low-carbon regeneration have also emerged as key priorities in industrial heritage transformation. Tian Jianglan developed a strategic framework for low-carbon retrofitting of existing industrial buildings, providing actionable guidelines for achieving low-carbon development in China's Yangtze River Delta region[32]. Meanwhile, Zhu Ruidong utilized spatial network analysis to design low-carbon renewal strategies for industrial heritage communities, offering data-driven solutions for integrating sustainability into industrial heritage redevelopment[33]. These studies emphasize the role of industrial heritage in low-carbon urban development, demonstrating how heritage conservation and sustainable urbanism can be mutually reinforcing.

In recent years, scholars have explored multi-objective optimization approaches to industrial heritage sustainability assessment, integrating energy simulations and building environment analyses to optimize low-carbon transformation strategies. Yuetao Wang et al. proposed a carbon-space network model for designing low-carbon industrial heritage communities, leveraging scientific methods to enhance carbon efficiency in heritage adaptive reuse[34]. These engineering-based evaluation methods provide rigorous quantitative assessments, yet they must be integrated with social and economic evaluations to achieve a more comprehensive interdisciplinary assessment framework.

Overall, environmental sustainability analysis introduces a "green benchmark" for industrial heritage transformation, ensuring that projects prioritize both economic and cultural benefits while maintaining ecological integrity. This aligns with global initiatives promoting "green heritage" and "ecological civilization", reinforcing industrial heritage's role as a public good that serves environmental restoration and climate resilience. By demonstrating how heritage conservation contributes to broader environmental goals, sustainability assessments can help secure public and governmental support, ensuring that industrial heritage projects align with global sustainability objectives.

（3）Cultural and Community Impact Assessment in Industrial Heritage Transformation

The success of industrial heritage transformation largely depends on its cultural and social impact. Compared to economic and environmental assessments, evaluating cultural and community influence is more complex, as it is difficult to quantify solely through mathematical models. As a result, research in this field often employs a combination of qualitative and quantitative methods, including Cultural Value Assessment (CVA), Public Participation Surveys, and Social Impact Assessment (SIA), to measure a project's effects on community identity and cultural life.

One crucial aspect of assessment is whether adaptive reuse projects help preserve and strengthen historical and cultural narratives. This includes evaluating whether industrial memories are passed down and whether cultural identity is enhanced through the project. Another critical factor is whether the transformation meets community needs and enhances residents' quality of life and well-being. Some scholars advocate for Lichfield's Community Impact Evaluation Model, which incorporates stakeholder perspectives into the assessment process[35]. This approach emphasizes that evaluations should not be conducted solely by experts but should also integrate community feedback, ensuring that the project aligns with public interests. For example, Nocca et al. developed well-being indicators to measure how heritage reuse influences residents' sense of place and psychological satisfaction[36].

To systematically assess cultural and community influence, several key indicators may be used, including the number of heritage education participants, frequency of community events, residents' awareness levels, and volunteer engagement rates. By continuously monitoring these indicators, researchers can determine whether an industrial heritage project has been truly "accepted by the community" and successfully "integrated into local culture." Cultural and community impact assessments introduce "soft" indicators to balance the "hard" economic and environmental metrics, making evaluation outcomes more comprehensive and holistic. This approach reflects a human-centered perspective, emphasizing how industrial heritage serves people and social development rather than existing merely as a preserved structure.

Cultural Value Assessment (CVA) focuses on the symbolic, historical, and identity-related aspects of industrial heritage. Recent studies have integrated geographic information system (GIS) spatial analysis and text mining to explore the significance of industrial heritage within urban cultural structures. For instance, Xia Tong et al. analyzed user comments from new media platforms to understand public perceptions of Third-Front industrial heritage, offering valuable insights into community-driven heritage transformation[37].

In addition to cultural value assessments, public participation surveys and social impact assessments (SIA) have been increasingly used to evaluate how industrial heritage transformation affects community relationships, residents' quality of life, and social cohesion. SIA methodologies often involve questionnaires, interview analyses, and focus group discussions to systematically collect and interpret stakeholder opinions. Liu Jiana's research on industrial heritage transformation in the Ruhr region of Germany provides an insightful case study, illustrating how adaptive reuse projects transformed industrial sites into community public spaces, thereby strengthening interactions among residents[38]. Similarly, Hu Huixin's research emphasized the crucial role of stakeholder engagement in industrial heritage redevelopment, particularly in enhancing community participation and fostering a sense of collective identity[39].

Overall, cultural and community impact assessment provides a holistic framework for understanding how industrial heritage interacts with society. By incorporating both expert evaluations and public participation, these assessments help ensure that heritage transformation projects are not just architectural or economic ventures but also meaningful cultural and social assets that enrich communities.

（4）Multidisciplinary Integrated Assessment Framework for Industrial Heritage Transformation

Given the complexity of industrial heritage transformation, many scholars and institutions have attempted to construct comprehensive evaluation frameworks that integrate multiple dimensions into a unified model. A typical approach involves developing "multi-indicator dashboards" or evaluation matrices, which combine quantitative indicators and qualitative judgments to reflect the overall performance of projects in the form of scores or indices. For example, Camoletto et al. proposed a multi-criteria model, in which each indicator is assigned specific weights and scoring criteria, ultimately aggregated into a final composite score or ranking[40]. The advantage of such a framework lies in its clear structure, facilitating cross-project comparisons and allowing flexible adjustments to the indicator set based on specific needs.

Other studies have incorporated the Balanced Scorecard (BSC) methodology, evaluating industrial heritage reuse projects from four dimensions: financial performance, community engagement (visitors and local residents), internal operations (management and maintenance), and long-term sustainability (learning and innovation). Additionally, international organizations have promoted "sustainability assessment toolkits", offering predefined templates and indicators that can be customized for different contexts. However, while comprehensive assessment frameworks strive for inclusivity, an excessive number of indicators may lead to operational complexity or data collection challenges. As a result, framework design must balance scientific rigor with practical feasibility. With the advancement of digital technologies, future assessment frameworks are expected to become more dynamic and intelligent, integrating real-time data—such as mobile signaling from tourists and energy consumption monitoring—to update indicators automatically, thereby improving timeliness and responsiveness in industrial heritage evaluation.

In recent years, researchers have developed various integrated assessment models to bridge the gaps between single-discipline approaches, combining expertise from economics, environmental science, social sciences, and cultural studies.

PESTLE Model (Political, Economic, Social, Technological, Legal, Environmental): A broad framework for analyzing the multidimensional impact of industrial heritage transformation, incorporating both macro-level policy analysis and micro-level site assessments.

DPSIR Model (Drivers, Pressures, State, Impact, Response): A widely used model linking industrial heritage conservation, environmental change, and socio-economic interactions. Babak Tavakoli et al. applied this model in Iran to analyze the environmental impact of energy systems, emphasizing the importance of assessing industrial heritage sites' environmental footprints[41].

Multi-Criteria Decision-Making (MCDM) Models: These models integrate Analytic Hierarchy Process (AHP), Delphi Method, and Fuzzy Logic Approaches to prioritize transformation strategies. For example, Claver Juan et al. applied multi-criteria decision analysis to evaluate sustainable reuse solutions for industrial heritage while considering urban integration[42]. Their research highlighted the role of industrial heritage in sustainable urban development.

System Dynamics Modeling: Ye Fangfang used system dynamics modeling to identify key factors influencing green regeneration in industrial heritage projects, offering strategic insights into conservation and adaptive reuse[43].

Comparative Case Study Analysis: Liu Shuling conducted a cross-case study to assess the suitability of different adaptive reuse strategies for industrial heritage, providing a practical methodology for evaluating industrial heritage values and determining reuse approaches[44].

These models merge quantitative analysis with qualitative insights, helping decision-makers balance cultural, economic, social, and environmental considerations. However, current interdisciplinary assessment models still face challenges related to data integration, weight assignment, and the standardization of qualitative-quantitative methodologies.

2.3.3 Localization and Innovation in the Assessment of Industrial Heritage in Italy

As one of the countries with the richest industrial heritage in the world, Italy has developed innovative evaluation methods with strong local characteristics in the assessment and transformation of industrial heritage. While influenced by international theories and practices, Italy has gradually formed an evaluation system that aligns with its cultural background and social needs in the process of protecting and reutilizing industrial heritage. Through this localized and innovative evaluation model, Italy has provided significant theoretical support and practical experience for global industrial heritage conservation and reuse. This paper explores the localization and innovation of industrial heritage evaluation in Italy, focusing on its technical characteristics and methodologies, covering aspects such as historical and cultural value assessment, social participation mechanisms, ecological restoration and sustainable development evaluation, as well as functional transformation assessment.

Table 2.6 Localized Innovations in Industrial Heritage Evaluation in Italy

Evaluation Dimension	Key Points	Advantages	Limitations and Challenges

Historical and Cultural Value Assessment	Integrates history of technology, anthropology, and theories of social memory; emphasizes "memory value" and intangible elements; focuses on "local meaning."	Interdisciplinary integration; stresses cultural identity and technological history; locally grounded	Highly subjective standards; limited cross-project comparability
Social Participation Mechanisms	Involves multi-stakeholder collaboration, public hearings, citizen surveys, educational programs; evaluation committees co-created by experts and the public.	Enhances public recognition and engagement; strengthens legitimacy of the evaluation process	Time-consuming; high coordination cost; outcomes easily influenced by participant structure
Ecological Restoration and Sustainability Assessment	Incorporates tools like EIA, SEA, LCA, and carbon footprint analysis; sets ecological performance indicators (e.g., restoration area, energy efficiency, resilience metrics).	Strong alignment with sustainability goals; clear technical pathways	High dependency on data and technology; requires large upfront investment; regional capacity gaps
Multifunctional Transformation and Operational Performance	Focuses on functional diversity and post-occupancy evaluation (POE); uses sensors, communication data, structural analysis to assess adaptability and feedback.	Technologically precise; strong operational orientation; supports dynamic improvement	Complex implementation; data integration challenges; requires ongoing maintenance efforts

Source: Compiled by the author

（1）Localization and Innovation in the Assessment of Historical and Cultural Value

The evaluation methods for industrial heritage in Italy place particular emphasis on the technical analysis of historical and cultural value, incorporating multidisciplinary theoretical frameworks from architectural history, technological history, and sociology. Building upon traditional architectural assessment methods, Italy's evaluation system has gradually integrated comprehensive assessments of social memory, cultural heritage, and production technology, striving to explore and present the historical value of industrial heritage from multiple dimensions. For instance, in assessing the value of the Lingotto Factory in Turin, besides considering its achievements as an early reinforced concrete structure, significant attention is also given to its connection with the rise of Turin’s automotive industry and its impact on the lives of working-class communities. Such evaluations require the integration of historical and anthropological methodologies to collect extensive contextual data.

Scholars in Italy have proposed that the "heritagization" process should enhance community awareness of heritage value, incorporating intangible historical memory into the evaluation system. While heritage protection laws and industrial heritage registers provide a fundamental framework for assessment, the key lies in how to systematically apply tools from architectural archaeology, social memory theories, and the history of production technology to conduct in-depth analyses. This approach evaluates the cultural and social significance of industrial heritage from both historical and technological perspectives by conducting detailed investigations into aspects such as architectural forms, raw materials, craftsmanship, workers’ history, and production processes. A study on Lombardy’s textile industry heritage emphasized the "memory value" of industrial heritage, suggesting that the emotional connection of former workers and communities to these sites should be considered as a reference factor in value judgments. This method reflects a sensitivity to local historical and cultural contexts, breaking away from the traditional expert-driven scoring model. Additionally, information obtained through oral history and public voting has, to a certain extent, influenced the conclusions of heritage value assessments.

Moreover, Italy’s evaluation system emphasizes the integration of intangible cultural heritage. In the assessment process, in addition to conducting a detailed survey of the physical structure of industrial heritage, consideration is also given to the social memory, workers’ culture, and technological transmission embedded within these sites. This approach seeks to explore the unique status and function of industrial buildings in local culture through historical research on production processes and workers' lives, emphasizing the cultural symbolic significance of buildings and sites, thereby providing theoretical support for their adaptive reuse. It can be said that Italy places greater emphasis on qualitative evaluation and local perspectives in assessing industrial heritage. The conclusions of such evaluations not only answer the question, "How important is this industrial heritage according to universal standards?", but more importantly, "What does it mean to our local community?" This innovation ensures that evaluation results align with local realities, making assessments genuinely serve the purpose of heritage conservation and reutilization.

（2）Localization and Innovation in Social Participation Mechanisms

The evaluation methods for industrial heritage in Italy place significant emphasis on social participation mechanisms, representing a key innovation in the global field of heritage conservation. Italy’s multi-level governance model ensures that industrial heritage assessment and reuse align with local needs and realities by incorporating the perspectives of local communities, cultural organizations, and academic institutions. In certain heritage projects, evaluations are no longer conducted exclusively by expert panels behind closed doors but instead involve community representatives, property owners, NGOs, and other stakeholders in open discussions. For instance, during the evaluation of the industrial port redevelopment in Genoa, the municipal government held multiple public hearings to collect citizens’ opinions on the heritage value and potential future uses of the site. This approach resembles a public evaluation process, where community members’ emotional attachment and practical needs serve as key criteria in determining the value of industrial heritage. As research has pointed out, if evaluations are dominated solely by expert discourse, certain intangible values of heritage may be overlooked. However, by involving stakeholder consultations, new dimensions of value can be discovered, and the evaluation results gain wider public legitimacy.

During the transformation of industrial heritage in Italy, citizen surveys, public forums, and feedback mechanisms are frequently conducted as an integral part of the evaluation process. The social participation approach employs both quantitative and qualitative analyses to determine whether industrial heritage redevelopment projects align with community interests and contribute to sustainable local economic growth. This evaluation method goes beyond the physical preservation of historic buildings by incorporating social needs, economic potential, cultural identity, and environmental quality into the assessment framework, ensuring that heritage transformation enhances social inclusivity and improves residents’ quality of life.

To institutionalize this participatory approach, certain regions in Italy have established heritage evaluation advisory committees, consisting of heritage experts, community leaders, business representatives, and other stakeholders. These committees collaborate to formulate evaluation criteria and discuss assessment results, ensuring a balanced and transparent process. Additionally, educational institutions have been integrated into the system, encouraging younger generations to participate in evaluation practices.

Furthermore, Italy has implemented a multi-stakeholder evaluation framework, particularly emphasizing cross-sector and interdisciplinary collaboration. Under government leadership, local authorities, NGOs, businesses, and communities participate collectively in the evaluation process. Through regular joint review meetings, interdisciplinary research initiatives, and expert panel discussions, industrial heritage evaluations in Italy are conducted not solely from a historical perspective but through a comprehensive lens that includes socioeconomic, ecological, and cultural identity factors. The localized innovation of this approach lies in its emphasis on both social and environmental benefits, providing long-term social validation and technical support for industrial heritage transformation projects.

Overall, Italy’s innovative approach to industrial heritage evaluation embodies the principle of “emerging from society”—designing mechanisms that ensure diverse voices are integrated into the evaluation process. This not only enhances the comprehensiveness and fairness of evaluations but also turns the assessment process itself into a means of promoting heritage value and fostering public consensus. As a result, the evaluation process lays a solid foundation of public support for subsequent conservation and redevelopment initiatives.

（3）Innovations in Ecological Restoration and Sustainability Assessment

In Italy’s industrial heritage transformation assessment system, the integration of ecological restoration and sustainable development represents another significant localized innovation. When addressing environmental challenges in industrial heritage redevelopment, Italy has developed localized evaluation indicators and methodologies tailored to its unique ecological and regulatory context. For instance, in the assessment of brownfield (industrial wasteland) redevelopment projects, environmental remediation outcomes are given special attention, with key evaluation criteria including soil remediation compliance levels, groundwater pollution control, increased green space area, and habitat diversity index. Compared to general project evaluations, Italy places greater emphasis on the "ecological performance" of historically polluted sites. Furthermore, various environmental organizations actively participate in the evaluation process, overseeing the development of assessment indicators to ensure strict adherence to environmental protection standards.

Green design technologies have become a crucial component of Italy’s industrial heritage evaluation framework, particularly for projects involving environmental contamination and land restoration. For example, life cycle analysis (LCA) and energy efficiency assessments have been integrated into the evaluation system to analyze the ecological impact of industrial heritage and the environmental benefits of its transformation. Italy's assessment methods do not merely evaluate the sustainability of building materials; they also calculate overall carbon emissions and energy consumption of projects to determine whether they align with low-carbon city initiatives and green building standards.

Additionally, Italy actively promotes the incorporation of ecological design principles into heritage redevelopment. During the assessment phase, projects are scrutinized for their use of renewable energy, energy-saving retrofits, and sustainability measures. In abandoned industrial zones, evaluation extends beyond the preservation and adaptive reuse of buildings to include soil and water pollution remediation, air quality improvement, and biodiversity restoration. These ecological restoration assessments typically involve environmental geology, water resource management, and ecology, employing Environmental Impact Assessments (EIA) and Ecological Carrying Capacity Evaluations to systematically analyze project sustainability and environmental friendliness.

Italy has effectively aligned industrial heritage ecological assessments with national sustainability objectives, resulting in the development of specialized indicator systems. Some local governments have mandated Environmental Impact Assessments (EIA) and Strategic Environmental Assessments (SEA) as prerequisites for industrial heritage redevelopment projects, ensuring that ecological factors hold a significant position in the evaluation process. Through these innovative practices, Italy has successfully established a monitoring system for "green transformation" outcomes, ensuring that industrial heritage projects not only preserve industrial culture but also enhance ecological conditions, achieving genuinely sustainable regeneration.

（4）Multifunctional Transformation and Functional Assessment Technologies

In response to the trend of adaptive multifunctional use of industrial heritage, Italy has integrated functional adaptability and operational performance into its assessment framework. Prior to confirming a redevelopment plan, simulation models and expert evaluations are employed to assess the compatibility between new functions and the original spatial characteristics of heritage sites. For instance, evaluations examine the feasibility of converting large equipment halls into exhibition spaces or the structural capacity of old factory buildings to withstand additional loads. These assessments involve structural engineering and building physics analyses to ensure that newly introduced functions do not compromise the physical integrity of the heritage site.

Beyond the initial adaptation phase, Italy places significant emphasis on post-occupancy evaluation (POE) once a project has been operational for a period of time. Through data collection on usage rates, visitor satisfaction, economic returns, and maintenance costs, these evaluations determine whether the transformation has met its intended objectives. For example, in the case of a factory repurposed as a museum, post-occupancy assessments analyze whether visitor numbers meet projections, how effectively exhibition spaces are utilized, and whether circulation layouts require adjustments. This data-driven functional evaluation provides a foundation for further refinements and optimizations.

To enhance quantitative analysis, researchers have introduced advanced technological tools into functional assessments. These include mobile communication data analysis, which tracks foot traffic patterns in cultural-commercial complexes to evaluate the contribution of different functional zones to overall visitor engagement. Additionally, IoT-based environmental sensors monitor indoor climate conditions, assessing the comfort levels of newly introduced functions and the effectiveness of technical systems within repurposed industrial spaces.

Unlike traditional single-use redevelopment models, Italy's industrial heritage transformation prioritizes the integration of multifunctional spaces. The assessment framework includes technical analyses of diverse adaptive uses, such as commercial, cultural, creative industries, and residential functions. Market demand studies, transportation accessibility assessments, and community impact evaluations are conducted to determine which functions best align with a given industrial heritage site, thereby enhancing economic viability and social impact.

For mixed-use projects, a key focus of functional assessment is the synergistic effect between different functions. Some Italian evaluation models have attempted to establish functional diversity indices and function integration metrics to measure the richness and interconnectivity of different uses within a site. In summary, Italy's approach to functional assessment is characterized by its precision and refinement. By combining engineering-based evaluations with real-time operational data, Italy ensures that industrial heritage transformations achieve effective functional performance and maintain technical reliability.

This evaluation methodology creates a feedback loop for complex multifunctional projects, allowing for continuous optimization and refinement. Ultimately, it maximizes the social, cultural, and economic benefits of industrial heritage reuse.

2.4 Comprehensive Theoretical Framework: Theoretical Support for Elemental System Synergistic Evaluation

The complexity of industrial heritage transformation necessitates an evaluation process that integrates multiple dimensions and scales. A single assessment method often fails to comprehensively capture the multifaceted effects of industrial heritage transformation. Consequently, recent research has increasingly moved toward constructing interdisciplinary, system-synergistic theoretical frameworks. The Elemental System Synergistic Evaluation Approach has emerged within this context, incorporating key perspectives from General System Theory, Synergetics, Sustainable Development Theory, Multi-Level Governance Theory, and Complex Adaptive System Theory. These theoretical foundations allow for a more holistic assessment of the performance and impact of industrial heritage transformations. This section will explore the theoretical support of Elemental System Synergistic Evaluation, focusing on four core perspectives: system theory and synergetics, sustainable development theory, multi-level governance theory, and complex adaptive system theory.

Table 2.7 Theoretical Foundations of Synergistic Evaluation in Element Systems

Theoretical Dimension	Core Concepts	Major Contributions	Representative Theories / Scholars	Evaluation Insights
Theoretical Dimension	Industrial heritage transformation is a complex system of interacting elements; emphasizes holism, dynamics, and synergy.	Provides systems thinking; focuses on interaction and feedback; strengthens synergistic effects	L. von Bertalanffy (General Systems Theory), H. Haken (Synergetics)	Incorporate feedback mechanisms; identify "order parameters"; focus on emergence and coupling

Systems Theory and Synergetics	Stresses the balance among the "triple bottom line" — economy, society, and environment — and intergenerational equity.	Establishes long-term value evaluation standards; guides eco-city development	John Elkington (Triple Bottom Line), Eco-City Theory	Apply three-dimensional indicator systems; assess ecological performance and intra-/intergenerational equity
Sustainable Development Theory	Advocates multi-actor collaborative governance and policy interaction; emphasizes deliberative democracy and public participation.	Enhances governance efficiency and legitimacy; promotes polycentric cooperation	Elinor Ostrom (Polycentric Governance), Jürgen Habermas (Deliberative Democracy), SNA Analysis	Set governance collaboration indicators; quantify public participation and governance network performance
Multi-level Governance Theory	Systems exhibit self-organization, feedback, and nonlinear evolution; emphasizes resilience and adaptive change.	Enhances dynamic assessment; introduces resilience and real-time response mechanisms	CAS Theory, Resilient City Theory	Introduce rolling evaluations and dynamic weighting; integrate real-time data and predictive modeling

Source: Compiled by the author

2.4.1 System Theory and Synergetics: A Holistic Understanding of Transformation

（1）Fundamental Principles of System Theory

General System Theory, introduced by Ludwig von Bertalanffy, posits that entities do not exist in isolation but are embedded within broader systemic structures. It provides a framework for understanding complex phenomena, asserting that a system's overall function exceeds the sum of its individual components, with internal elements interacting through intricate feedback mechanisms that shape its behavior and functionality.

Applying this principle to industrial heritage transformation implies that assessments must consider the interconnections among heritage sites, environmental factors, economic structures, and societal dimensions. An industrial heritage project is not merely a cultural artifact but also an integral part of urban economic and environmental systems. It is subject to external influences, including policy, market dynamics, and ecological constraints, while also exerting reciprocal feedback effects on these external systems.

This study incorporates system theory principles by integrating external environmental variables into its evaluation framework, measuring both the external influences on a project and its broader systemic impacts. Moreover, system theory's emphasis on feedback and regulation mechanisms informs our model's dynamic adjustment functionality. For instance, if an evaluation reveals a severe deficiency in a particular metric, feedback mechanisms prompt decision-makers to adjust intervention strategies to maintain system stability. In the context of industrial heritage transformation assessment, system theory provides three core principles.

Holism: Industrial heritage should not be regarded merely as individual buildings or isolated spaces but as integral components of urban development, cultural identity, economic vitality, and ecological balance. Consequently, evaluations must integrate multiple levels of impact, including heritage's role in shaping urban identity, enhancing social cohesion, and contributing to regional economic and environmental well-being.

Dynamism: Industrial heritage transformation is a dynamic evolutionary process, requiring value assessments that span different temporal dimensions. Evaluations should not only analyze current conditions but also forecast future trajectories. For example, an industrial site initially repurposed for tourism may gradually evolve into a creative industry hub or mixed-use commercial space. Therefore, assessment frameworks should encompass short-term, mid-term, and long-term developmental pathways.

Hierarchy: Industrial heritage influences multiple spatial scales, from individual sites to communities, cities, and entire regions. Evaluation frameworks must support multi-scalar analysis. For example, an industrial heritage transformation not only revitalizes its immediate surroundings but can also serve as a national cultural symbol, enhancing the city's global recognition. To ensure comprehensiveness, assessment frameworks should establish hierarchically structured evaluation criteria that correspond to different scales of impact.

System theory thus provides a structured analytical framework for industrial heritage transformation, ensuring that evaluation systems extend beyond isolated buildings or single-use functions. It reinforces the importance of holistic, cross-disciplinary coordination, enabling balanced development across economic, social, and ecological dimensions.

（2）The Introduction of Synergetics

Synergetics, proposed by Hermann Haken, emphasizes the collaboration and self-organization of elements within a system, asserting that a system's overall behavior emerges dynamically from the interactions among its subsystems. When applied to industrial heritage transformation evaluation, this perspective focuses on three key aspects: how multiple objectives (e.g., conservation and development) coordinate, how multiple stakeholders collaborate, and how multiple evaluation criteria interact to promote systemic synergy.

According to synergetics principles, a system's order arises from the synergy among its elements. In the context of industrial heritage transformation, a project is more likely to achieve sustainable and positive outcomes when economic, social, and environmental objectives progress in tandem. Thus, our evaluation framework places great emphasis on assessing the degree of synergy—for instance, whether economic benefits and social benefits increase simultaneously, or whether investment in conservation is proportionate to the returns from utilization. If one objective is achieved at the expense of another, this is regarded as insufficient synergy.

Additionally, synergetics introduces the concept of order parameters, referring to key variables that drive the evolution of the entire system. In industrial heritage projects, these parameters could include "cultural tourism footfall" or "community participation rates", as changes in these indicators may trigger subsequent shifts in other evaluation metrics. Identifying and monitoring these order parameters helps grasp the transformation trajectory of a project and its phased characteristics.

Thus, synergetics reshapes our evaluation approach, shifting the focus from isolated, itemized scoring to an integrated analysis of interdependencies among evaluation indicators. This reflects an innovative integration of systemic thinking and holistic assessment into industrial heritage evaluation.

The introduction of synergetics into industrial heritage transformation evaluation significantly enhances the comprehensiveness and strategic foresight of assessment methodologies. By focusing on the interactions among transformation elements, the degree of synergy across multiple objectives, and the predictive modeling of systemic evolution, synergetics provides a more robust foundation for guiding transformation strategies.

Through synergetics-driven assessment, industrial heritage projects can achieve more integrated, balanced, and sustainable outcomes, ensuring that conservation, development, and community engagement progress in a mutually reinforcing manner.

2.4.2 Sustainable Development Theory: Long-Term Value Assessment in Industrial Heritage Transformation

The objectives of industrial heritage transformation extend beyond short-term spatial reutilization; they should serve long-term societal, economic, and environmental sustainability. Since industrial heritage projects often encompass historical conservation, urban renewal, ecological restoration, and industrial restructuring, their assessment must be grounded in a scientifically robust theoretical framework to ensure the realization of long-term value. Sustainable development theory provides a systematic theoretical foundation for industrial heritage transformation, ensuring that conversion outcomes not only address contemporary needs but also generate positive impacts for future generations.

（1）The Triple Bottom Line Model: Coordinated Development of Economy, Society, and Environment

In the field of sustainable development, the Triple Bottom Line (TBL) model, proposed by John Elkington, asserts that any project should simultaneously pursue economic prosperity, social equity, and environmental well-being. When applied to industrial heritage transformation evaluation, this model mandates that evaluation frameworks comprehensively address three dimensions—economic, social, and environmental—and analyze their interrelations. Many scholars have already incorporated TBL’s three-dimensional sustainability indicators into industrial heritage evaluation models.

This study explicitly adopts the TBL model as a guiding principle in its theoretical framework: all evaluation indicators are designed to equitably cover all three dimensions, and assessment methods are structured to ensure that no single dimension is overlooked. For example, if a project demonstrates economic success but exerts a negative environmental impact, our evaluation will reflect such unsustainability, rather than labeling it as an "outstanding" project solely based on economic performance. The integration of the Triple Bottom Line model ensures that evaluation results align with sustainable development goals and do not prioritize economic returns at the expense of environmental degradation or social exclusion.

Furthermore, sustainable development also emphasizes intra-generational equity and inter-generational equity. In terms of intra-generational equity, we assess whether the project balances the interests of different stakeholder groups (such as the government, investors, and local residents) to ensure that no single group unilaterally benefits or suffers losses. In terms of inter-generational equity, we consider the project's impact on future resources and development, such as whether the redevelopment preserves spaces for future sustainable use. In summary, the Triple Bottom Line model provides a comprehensive and balanced benchmark for industrial heritage transformation assessment, guiding us in pursuing a synergistic effect of economic, social, and environmental benefits[45].

（2）Ecological City Theory: Environmentally Friendly Industrial Heritage Transformation

The theory of ecological cities represents a concrete application of sustainable development in urban contexts, emphasizing the harmonious coexistence between urban growth and the natural environment. It asserts that the adaptive reuse of industrial heritage should be assessed from the perspectives of resource conservation, green infrastructure, and low-carbon development. Integrating the concept of ecological cities into industrial heritage reuse means recognizing such projects as integral components of environmentally friendly urban construction. Theoretically, an ecological city prioritizes resource efficiency, pollution reduction, and the protection of ecosystems. Consequently, assessment frameworks incorporate indicators such as energy utilization efficiency and pollutant emission reductions to determine whether a project follows an ecologically sustainable path. For example, if a project employs renewable energy or green building technologies, it is awarded additional points in the environmental dimension; if the redevelopment contributes to urban green spaces and ecological services, it is considered a positive factor in ecological city-building.

Equally important is the consideration of urban resilience—whether a project enhances a city's capacity to cope with environmental and climate challenges. This aspect extends the ecological city theory, as seen in cases where abandoned industrial sites are transformed into rain gardens or flood mitigation parks, thereby improving urban disaster resilience. During the evaluation process, such "resilience benefits" are factored into the environmental impact assessment. The ecological city theory reminds us that industrial heritage transformation is not merely about repurposing old structures but also about seizing an opportunity to improve urban environments. Therefore, the assessment approach adopts an "incremental" perspective—comparing pre- and post-project environmental conditions to determine whether the redevelopment results in net ecological improvements. In conclusion, embedding sustainable development theory into assessment methodologies establishes a long-term value standard for industrial heritage transformation—requiring not only a present-day balance of economic, social, and environmental benefits but also a forward-looking approach that considers its positive contributions to future cities and ecosystems. This ensures that industrial heritage transformation genuinely serves as a catalyst for sustainable urban development.

2.4.3 Multi-Level Governance Theory: Transformation Policies and Social Mechanisms

The transformation of industrial heritage involves multiple stakeholders, including governments, markets, communities, and academic institutions. Therefore, it requires an evaluation from a multi-level governance perspective to understand the roles of different governance actors in the transformation process and their collaborative mechanisms. This theory emphasizes how governance actors across various levels and sectors establish interactive mechanisms in complex policy environments to ensure the fairness, sustainability, and efficiency of industrial heritage transformation.

（1）Polycentric Governance Theory: Cross-Level Governance Models

The theory of polycentric governance posits that complex public affairs should be managed through multiple, independent but cooperative decision-making centers rather than a centralized authority. Applied to industrial heritage transformation, this means that central governments, local governments, community organizations, and private entities all participate in decision-making, each fulfilling distinct roles while coordinating efforts. Theoretically, this governance structure enhances decision-making flexibility and efficiency, facilitating information flow across different levels.

This study incorporates a polycentric perspective to evaluate governance effectiveness by assessing the contributions and interactions of various levels of stakeholders. For instance, governance indicators are designed to measure policy support from central and regional levels, execution and management capabilities at the local level, and the extent of public participation. When a particular governance level is absent or lacks coordination, projects often face obstacles. For example, if local governments fail to integrate industrial heritage into urban planning, the polycentric governance mechanism remains incomplete.

Through policy document analysis and stakeholder interviews, successful cases in Italy reveal a key insight: "Heritage preservation requires a certain degree of decentralization in decision-making and financing, with designated departments at each level and full public participation in every step of the planning process." Based on this, governance evaluation includes an assessment of the degree of decentralized coordination, examining whether intergovernmental and interdepartmental cooperation functions smoothly. Multi-level governance theory thus integrates macro-governance considerations into the assessment framework, enabling researchers to identify governance-related obstacles in project implementation and propose targeted improvements.

（2）Deliberative Democracy and Collaborative Governance Mechanisms

The theory of deliberative democracy, proposed by Jürgen Habermas, advocates for decision-making through open dialogue and negotiation, making it particularly applicable to cases requiring public participation. Industrial heritage transformation projects often involve public interests, and the principles of deliberative democracy provide a framework for enhancing the legitimacy and inclusiveness of decision-making. In evaluating participation mechanisms, deliberative democracy serves as a benchmark to assess whether projects have established adequate channels for public consultation, hearings, and feedback. For example, if a project held multiple community consultation meetings during the planning phase, its public participation level would be rated high. Conversely, if the decision-making process was closed, the governance mechanism would be considered in need of improvement.

One fundamental aspect is ensuring the legitimacy of civic participation. Industrial heritage transformation is not merely a technical and economic issue; it also involves social equity, cultural identity, and community well-being. Deliberative democracy emphasizes the inclusion of local residents, cultural institutions, academia, and business sectors in the decision-making process, ensuring that diverse interests are incorporated into policy frameworks. Another crucial aspect is the multi-level coordination in policy execution. Deliberative governance should not be limited to the policy-making stage but should extend into implementation. For instance, the reuse of industrial heritage involves long-term operations and maintenance, and deliberative mechanisms can help in policy execution, resource allocation, and post-implementation adjustments to ensure continuous optimization.

In addition, collaborative governance highlights the necessity of cooperation between governments, businesses, and civil society organizations. The evaluation model examines the effectiveness of multi-stakeholder collaboration, assessing whether governments have established public-private partnerships and whether NGOs participate in project management. The degree of collaboration can be quantified through indicators such as the number of signed cooperation agreements and the frequency of jointly organized activities. A case study on Oberschöneweide, for instance, found that both spontaneous community initiatives and official interventions played a role in shaping the project's development. Based on such findings, the inclusion of a collaborative governance index in the evaluation framework allows for a more comprehensive assessment of stakeholder cooperation in industrial heritage transformation projects.

By integrating deliberative democracy and collaborative governance theories, the governance evaluation framework accounts for both vertical coordination across different levels of government and horizontal cooperation among various sectors and public participants. This dual approach provides a more holistic measure of the institutional safeguards and societal foundations that support industrial heritage transformation.

（3）Social Network Analysis: Interactions Among Governance Actors

Industrial heritage transformation projects involve a complex network of relationships among various stakeholders, including government agencies, enterprises, experts, and communities. Social Network Analysis (SNA) provides a quantitative tool to examine how governance actors in industrial heritage transformation are interconnected, exchange information, and collaborate. Theoretically, an efficient governance network should have a moderate level of centralization (with a core leader) while also being multi-centered and highly interconnected (with strong ties among various actors). The structure and strength of this governance network directly influence the effectiveness of policy implementation.

When evaluating governance performance, the network analysis approach can be introduced by investigating the frequency of interactions and the depth of collaboration among different stakeholders, then visualizing the relationships through network diagrams and calculating key indicators such as network density and centrality. For example, in a specific industrial heritage project, if local government authorities, developers, and community associations maintain regular communication and cooperation, they form a closely connected core network with high centrality and dense linkages, which typically correlates with effective coordination. Conversely, if a key stakeholder, such as the community, is marginalized within the network, structural holes may emerge, leading to information asymmetry or conflicts.

By conducting node analysis of governance actors, it is possible to identify the most influential players in the industrial heritage transformation process and determine their critical roles in policy formulation and implementation. This helps to highlight which institutions dominate resource allocation and policy adjustments and which social organizations can enhance policy execution effectiveness. Moreover, SNA facilitates the analysis of how policies are disseminated across different levels of government and stakeholders, ensuring that information flows efficiently, thereby improving implementation outcomes.

Additionally, by examining the relationships among government institutions, market entities, social organizations, and academic institutions, SNA helps optimize policy coordination mechanisms, improving interdepartmental communication, reducing information gaps, and minimizing policy blind spots. The application of network analysis provides a quantitative tool for assessing governance systems in industrial heritage projects, making policy formulation and execution more transparent and effective while pinpointing weaknesses in governance structures.

This study, through interviews and archival research, attempts to reconstruct the governance network of case study projects to support qualitative evaluations. Although comprehensive quantitative SNA could not be conducted due to data constraints, this theoretical perspective guides our attention to hidden relational factors and informs recommendations in evaluation reports. For instance, some findings suggest that certain projects should strengthen direct dialogue between the government and communities instead of relying solely on intermediary organizations. These recommendations stem from an analysis of the governance network, demonstrating the practical value of this approach.

Overall, SNA provides a valuable methodological tool for visualizing governance relationships, helping evaluators identify weak links and key hubs in governance structures, thus informing targeted strategies for optimizing governance mechanisms in industrial heritage transformation.

2.4.4 Complex Adaptive Systems Theory: Dynamic Evaluation of Transformation

Industrial heritage transformation is a complex adaptive system (CAS) in which the transformation process consists of multiple interacting elements and layers, exhibiting self-organization and nonlinear evolution characteristics. This process not only involves the physical renovation and functional repurposing of buildings but also intertwines with economic, social, cultural, and technological changes. Due to the high level of uncertainty and dynamic nature of industrial heritage transformation, traditional static evaluation methods fail to comprehensively capture the complex interactions and nonlinear changes within this process. The dynamic nature of industrial heritage transformation can be understood through Complex Adaptive Systems (CAS) theory, which posits that systems are composed of interacting agents with self-adaptive and evolutionary capabilities, adjusting in response to internal and external changes. Viewing industrial heritage projects as CAS helps in designing evaluation frameworks that incorporate temporal sequences and feedback mechanisms to improve adaptability.

（1）Feedback Mechanisms and Dynamic Adaptation

Industrial heritage transformation operates within a continuously evolving environment, where various system components—including policy, market forces, technological advancements, cultural shifts, and social demands—interact with each other, often resulting in nonlinear changes. Thus, the evaluation of industrial heritage transformation must incorporate dynamic feedback mechanisms to reflect the evolutionary and adaptive nature of the system at different stages. The introduction of feedback mechanisms allows for timely identification of system state changes throughout the transformation process and enables adaptive adjustments based on real-world conditions.

CAS emphasizes feedback loops, where system outputs influence future inputs, thereby enabling self-adjustment. In the context of industrial heritage transformation, problems or successes encountered at one stage should inform decision-making in subsequent stages, leading to adjustments in strategies and implementation approaches. The evaluation framework in this study integrates phased evaluation and feedback modules, ensuring that transformation pathways can be dynamically modified as the project progresses. This approach is akin to "rolling evaluations", which ensure that project pathways remain flexible and adjustable.

CAS theory also highlights that evaluation standards may need to be adjusted as the system evolves. For instance, in the initial phase, emphasis may be placed on planning and process evaluations, whereas in the later stages, the focus shifts to operational performance and economic sustainability. This dynamic weighting adjustment is incorporated into our evaluation model.

Through case studies of successful projects, we have observed that flexibility and adaptability are key factors for project success. For example, during economic downturns or shifts in policy, successful projects have adjusted operational models in real time. Consequently, our evaluation framework includes adaptability indicators, such as the project management team's ability to modify plans in response to environmental changes and the diversification of funding sources to mitigate reliance on a single financial stream. These indicators are derived from CAS principles, which suggest that the more complex the environment, the greater the system's need for adaptability to maintain resilience.

With advancements in digital technology, real-time data monitoring and quantitative modeling have become essential tools for evaluating industrial heritage transformation. Some industrial heritage projects in Italy have adopted real-time monitoring systems using sensors, satellite remote sensing, and social media data to continuously track environmental changes, traffic flow, and social interactions in project areas. These data are then processed using quantitative simulation models to predict potential changes throughout the transformation process.

For instance, by simulating different transformation scenarios, evaluators can assess the impact of various interventions on traffic congestion, commercial activity, and environmental pollution. Decision-makers can then use predictive analytics to adjust strategies dynamically based on real-time changes.

This dynamic adaptation evaluation model not only helps identify immediate system needs but also provides long-term data-driven insights for future policy planning and strategic adjustments. By integrating continuous monitoring and real-time adjustments, the feedback mechanism helps mitigate risks associated with information delays or unforeseen events, ultimately enhancing the feasibility and sustainability of transformation projects.

Overall, Complex Adaptive Systems (CAS) theory provides a framework for understanding the dynamic, evolving nature of industrial heritage transformation, ensuring that evaluation models remain responsive, data-driven, and adaptable to changing conditions.

（2）Resilient Cities Theory

Resilience is an extension of CAS in the field of urban and heritage studies, referring to a system’s ability to withstand shocks and recover quickly. Industrial heritage transformation should be integrated into urban resilience strategies. The concept of resilient cities emphasizes the adaptability and recovery capacity of urban systems, particularly in responding to economic fluctuations, social changes, and environmental challenges, ensuring that cities can effectively cope with these shifts and recover from them. The transformation of industrial heritage involves not only the renewal of building structures and functions but also the adaptation of cities to dynamic changes. Therefore, incorporating system resilience analysis can help assess a project's capacity to withstand pressure and recover in complex contexts. For example, a successfully repurposed industrial park can mitigate the impact of economic structural transformation by providing new employment opportunities and functions; a site converted into urban green space can enhance a community’s resilience against disasters such as floods or extreme heat.

When assessing the resilience of industrial heritage transformation, the primary focus is on several aspects. Economic resilience examines whether the project can effectively adapt to market changes and withstand external shocks such as economic downturns or industrial transformation. Social resilience analyzes whether the project can promote social integration and cultural identity, particularly in the face of social change or shifts in community structure, ensuring that the interests of local residents are safeguarded and that social inclusivity is maintained. Environmental resilience evaluates the project’s ability to respond to climate change, natural disasters, and other environmental risks, including strategies such as building energy efficiency, resource recycling, and ecological restoration. These assessment elements help decision-makers remain sensitive to future changes throughout the project's implementation, providing a safeguard for long-term sustainable development.

The theory of resilient cities emphasizes that in evaluating long-term impacts, it is essential to determine whether a project enhances the resilience of a city or community. For instance, if a project increases the economic diversity of a region and reduces its dependence on a single industry, the community will be more resilient to economic fluctuations, which can be positively reflected in socio-economic benefits. Similarly, in terms of environmental resilience, projects that increase rainwater retention capacity or expand urban green corridors are considered to contribute to resilience. Integrating resilience into the assessment allows for evaluating a project's preparedness for future uncertainties. Particularly in the context of climate change and economic globalization, this dimension holds significant practical value. Industrial heritage projects that are designed to be flexible and adaptable—such as spaces that can be repurposed or functions that can be adjusted—also demonstrate resilience, which is reflected in the evaluation of innovation indicators.

Overall, the introduction of CAS and resilience theory ensures that the assessment framework incorporates temporal dimensions and considerations of uncertainty. Industrial heritage transformation projects are not static, and the evaluation process seeks to capture their evolutionary trajectory and adaptive capacity, providing deeper insights than static assessments. This helps decision-makers take appropriate measures based on changes, ensuring that industrial heritage transformation not only succeeds in the present but also continues to function effectively in the future.

The theory of complex adaptive systems provides an evaluation framework for industrial heritage transformation based on dynamic evolution and feedback mechanisms, helping us understand how various elements within the system interact through self-organization and nonlinear processes. Through real-time data monitoring and quantitative simulation methods, assessments can capture dynamic changes in the transformation process, offering real-time decision-making support. The theory of resilient cities, on the other hand, incorporates adaptability and recovery capacity as core elements, guiding industrial heritage transformation assessments to consider existing resources and functions while also addressing future environmental changes and social demands. By integrating these theories, industrial heritage evaluation focuses not only on the short-term transformation outcomes but also on long-term sustainability and system resilience, ensuring that each step in the transformation process can adapt to an ever-changing socio-economic environment.

2.5 Summary of This Chapter

This chapter systematically reviews the theoretical and practical studies on industrial heritage transformation through a literature review. From a global perspective, the concept of industrial heritage conservation has evolved from its initial emergence to a more developed framework, with the establishment of international guidelines providing direction for various national practices. The introduction of interdisciplinary theories has diversified perspectives on the conservation and adaptive reuse of industrial heritage, while contemporary explorations of comprehensive transformation models reflect the trend of industrial heritage development in synergy with urban, environmental, and economic factors.

Italy, as the focal point of this study, demonstrates distinct characteristics in its industrial heritage transformation strategies, emphasizing cultural identity, exploring diverse reuse pathways, and implementing multi-stakeholder collaborative governance. These features provide valuable case studies for in-depth analysis.

In terms of evaluation methods, the combination of traditional and emerging tools, along with the continuous development of interdisciplinary assessment models, has enhanced the ability to comprehensively assess the value and impact of industrial heritage projects. Finally, the integration of systematic theories such as systems theory and sustainable development has laid the theoretical foundation for establishing an element-based system synergy evaluation framework. This allows the research to take a holistic perspective, considering both long-term and dynamic aspects of industrial heritage transformation.

In conclusion, research on industrial heritage transformation has achieved significant progress over the past two decades but remains in a state of continuous evolution. Future studies should focus on further theoretical integration and practical validation of evaluation frameworks to optimize assessment methods. This will better support industrial heritage in playing an active role in sustainable urban development.

3 The Elemental System Construction of Industrial Heritage Transformation

3.1 Extraction of Reference Elements

In the construction of the elemental system for industrial heritage transformation, the rational selection and extraction of reference elements with multidimensional guiding significance are crucial to ensuring the scientific and systematic nature of the research. Industrial heritage transformation encompasses multiple dimensions, including historical value, cultural inheritance, social needs, economic development, and environmental protection. Therefore, the evaluation and transformation processes must integrate diverse sources of information and perspectives.

This study selects four authoritative documents from different levels and regions as reference bases: the Equitable and Sustainable Well-being Index (BES Index) from the Italian National Institute of Statistics, the New European Bauhaus Initiative (NEB) launched by the European Union, the "European Quality Principles" issued by the International Council on Monuments and Sites (ICOMOS), and the "National Industrial Heritage Management Measures" published by China's Ministry of Industry and Information Technology. These documents provide extensive theoretical and practical guidance from national, regional, and global perspectives, ensuring the comprehensiveness and applicability of the extracted elements.

3.1.1 Key Reference Documents

（1）Italian National Institute of Statistics: Equitable and Sustainable Well-being Index (BES Index)

The BES Index (Benessere Equo e Sostenibile, or Equitable and Sustainable Well-being Index) is a comprehensive socio-economic evaluation system at the national level in Italy. It aims to go beyond the traditional GDP framework by incorporating three dimensions—economic, social, and environmental—to measure sustainable development and societal well-being. The BES Index includes multiple assessment indicators, such as income distribution, education, health, and environmental quality, providing a holistic reflection of societal well-being. The selection of the BES Index as a reference is based on the following two reasons.

Regional Relevance: Turin, as one of Italy's major industrial cities, has extensive experience in industrial heritage protection and transformation. Given that this study focuses on Turin and other Italian cities, the BES Index provides a relevant evaluation framework that aids in understanding the transformation of industrial heritage in these urban contexts.

Alignment with Transformation Goals: The multidimensional evaluation approach of the BES Index aligns closely with the objectives of industrial heritage transformation. The transformation of industrial heritage involves not only the adaptive reuse of buildings and spaces but also the enhancement of social well-being, environmental sustainability, and diversified economic development. The BES Index establishes a theoretical foundation for constructing the elemental system, facilitating an in-depth analysis of the balance and coordination between different dimensions during the transformation process.

（2）European Union: New European Bauhaus Initiative (NEB)

The New European Bauhaus (NEB) is an interdisciplinary innovation initiative launched by the European Union, with core values centered on sustainability, aesthetics, and inclusivity. Its goal is to integrate culture, art, and ecological development into architectural and urban design practices, emphasizing a holistic and human-centered approach to design. NEB advocates for innovative design to enhance social well-being, promote the green economy, and foster an inclusive society. The rationale for selecting the New European Bauhaus Initiative as a reference includes the following two aspects.

Regional and International Influence: As a transnational initiative, NEB focuses on balancing ecological restoration and cultural innovation in industrial heritage transformation. It has significant regional and international influence, particularly in advocating for sustainability and social inclusivity, which are essential aspects of industrial heritage transformation. The initiative provides a conceptual foundation for ensuring that cultural heritage preservation and environmental protection are harmoniously integrated in the redevelopment process.

Alignment with Design Innovation and Social Value: NEB places a strong emphasis on design innovation as a means to enhance social well-being, which is highly relevant to the adaptive reuse and transformation of industrial heritage. Specifically, in promoting the revitalization and repurposing of industrial sites, NEB offers valuable innovative perspectives on balancing aesthetics, functionality, and sustainability within the transformation process.

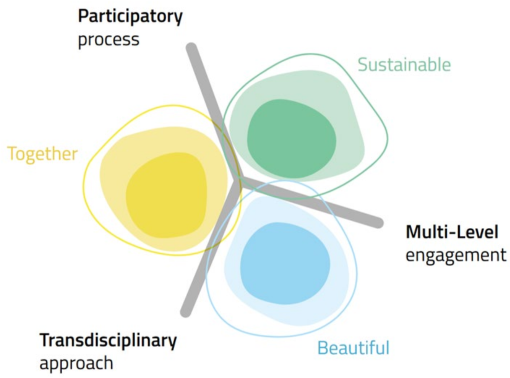


Figure 3.1 Diagram of NEB Values

Image Source: Official NEB Values Document

（3）International Council on Monuments and Sites (ICOMOS): European Quality Principles

The European Quality Principles is a guiding document formulated by the International Council on Monuments and Sites (ICOMOS) for the protection and utilization of cultural heritage, particularly focusing on interventions funded by the European Union that may impact cultural heritage sites. These principles encompass key aspects such as knowledge-based approaches, public interest, compatibility, proportional intervention, insight, sustainability, and good governance, offering a systematic framework for the transformation and adaptive reuse of industrial heritage. The selection of this document as a reference is based on its global applicability and theoretical authority.

Global Perspective and Applicability: The European Quality Principles serves as a global reference document applicable to the preservation and reuse of industrial heritage across different regions and cultural contexts. Its emphasis on compatibility, sustainability, and good governance provides an international theoretical framework for guiding industrial heritage transformation projects.

Balancing Historical Integrity and Modern Needs: By highlighting "proportional intervention" and "compatibility," the document encourages industrial heritage transformation that maintains historical value while adapting to contemporary urban demands. This approach to harmonizing heritage conservation with modern development offers a solid theoretical foundation for constructing the element-based system in this study.

（4）Ministry of Industry and Information Technology of China: National Industrial Heritage Management Measures

The National Industrial Heritage Management Measures is a regulatory document formulated by China’s Ministry of Industry and Information Technology, specifically for the protection and utilization of industrial heritage. It clearly defines the recognition standards, management responsibilities, and fundamental principles for the preservation and adaptive reuse of industrial heritage. This document provides a comprehensive evaluation system, assessing industrial heritage based on its historical, technological, artistic, and social value, while also proposing measures to ensure the sustainable development of industrial heritage during its transformation process. The rationale for selecting this document as a reference is based on its regional adaptability and practical guidance.

Strong Practical Operability: The document establishes a systematic management framework for industrial heritage protection in China, making it highly practical and actionable. When implementing industrial heritage transformation in China, this document serves as a reference for developing evaluation standards and transformation strategies, ensuring the legitimacy and standardization of the process.

Localized Support: In addition to focusing on industrial heritage protection, this document emphasizes cultural continuity, ecological restoration, and comprehensive assessment methods, providing localized support and practical guidelines for constructing an element-based system tailored to the Chinese context.

Through the comprehensive analysis of these four authoritative documents, this study systematically extracts multidimensional reference elements that hold guiding significance for constructing an element-based system for industrial heritage transformation. These documents, originating from national, regional, and international levels, provide rich theoretical and practical guidance for industrial heritage transformation. By integrating perspectives from cultural, economic, social, and ecological dimensions, this study ensures the comprehensiveness and applicability of the element-based system. Moving forward, this framework will support further exploration into achieving sustainable and multidimensional synergies in industrial heritage transformation, offering both theoretical insights and practical implications for future research and applications

3.1.2 Element Extraction and Analysis

Ensuring comprehensiveness and systematic rigor is crucial when constructing an element-based system for industrial heritage transformation. The process of element extraction not only involves identifying the specific needs of current transformation projects but also requires drawing upon and incorporating existing evaluation frameworks from both domestic and international sources. The objective is to ensure that the selected elements encompass multidimensional aspects and effectively evaluate the various value dimensions of industrial heritage throughout the transformation process. This study primarily integrates multiple theoretical frameworks to categorize and refine these elements, providing a solid theoretical foundation for subsequent evaluation models and transformation strategies. The following section outlines the specific contributions of the four key reference documents in the process of element extraction and analysis.

（1） The Contribution of BES Index's Multidimensional Well-being Framework to Element Classification

The BES Index moves beyond the traditional single-dimensional evaluation of economic growth, instead measuring national development levels through multiple dimensions such as social well-being, economic sustainability, and environmental quality. This framework provides critical insights for constructing the element-based system in this study. It highlights the importance of industrial heritage transformation extending beyond economic considerations to comprehensively evaluate its impact on social equity, environmental sustainability, and urban well-being.

Consequently, during the element extraction process, specific attention is given to indicators such as employment opportunities, cultural identity, flexible space utilization, green infrastructure, and carbon neutrality goals. These elements serve as key metrics for assessing the long-term impact of industrial heritage adaptation on urban development and societal progress, ensuring alignment with fundamental sustainability principles.

Table 3.1 Extracted and Transformed Elements from BES Index

BES Indicator	Transformed Elements
Safety	Regional Security
Service Quality	Service Industry Activity Level
Work-Life Balance	Employment Rate

BES Indicator	Transformed Elements
Politics and Institutions	Multi-Level Participation (Local/Interregional/Global)
Innovation, Research, and Creativity	Project Innovation Level, Cultural Activity Level
Environment	Construction and Material Efficiency, Energy Savings, System Circularity
Landscape and Cultural Heritage	Planning Tool Application Level, Conservation Awareness, Structural Compatibility
Education and Training	Intellectual Clustering, Education Level, Management Communication Level
Health	Cleanliness and Health Level, Cultural Welfare Level
Economic Well-being	Economic Self-Sufficiency, Capital Attraction, Reinvestment Participation, Real Estate Value
Social Relations	Identity Recognition, Social Inclusivity, Community Cooperation Level
Subjective Well-being	Subjective Happiness Level

Source: Compiled by the author based on original BES documents

（2）The Influence of NEB Values on Industrial Heritage Reuse Strategies

The New European Bauhaus (NEB) initiative's core values—aesthetics, sustainability, and inclusivity—directly shape the strategic direction of industrial heritage transformation. Compared to the BES framework, which focuses primarily on social well-being, NEB places greater emphasis on the design quality of industrial heritage reuse and its role in shaping urban cultural identity.

As a result, during the element extraction process, particular attention is given to indicators such as multilevel participation, interdisciplinary approaches, social inclusivity, cultural innovation, and the quality of public spaces. These elements not only contribute to enhancing cultural identity in industrial heritage projects but also promote functional diversity within modern urban regeneration efforts.

Table 3.2 Comparison of NEB Values and Work Principles Across Different Vision Levels

Values / Work Principles	Vision Level 1	Vision Level 2	Vision Level 3
Aesthetics	Activation	Connection	Integration

Values / Work Principles	Vision Level 1	Vision Level 2	Vision Level 3
Sustainability	Reuse	Circularity	Regeneration
Inclusivity	Inclusion	Consolidation	Transformation
Participatory Process	Consultation	Co-Development	Autonomy
Multi-Level Participation	Localized Actions	Cross-Level Operations	Globalized Actions
Interdisciplinary Approach	Multidisciplinary	Interdisciplinary	Transdisciplinary

Source: Compiled and translated by the author based on original NEB value documents

（3）The Contribution of ICOMOS European Quality Principles to the Balance Between Preservation and Development

The seven core principles outlined by ICOMOS European Quality Principles emphasize the scientific, rational, and sustainable approach to cultural heritage preservation, providing a systematic framework for assessing industrial heritage transformation. The key contribution of this document in element extraction lies in its focus on quality control in cultural heritage interventions, ensuring that repurposed industrial heritage balances both cultural value and economic-social development needs.

Thus, this study places particular emphasis on knowledge systems, public interest, compatibility, proportionate intervention, sustainability, and good governance. These elements not only aid in evaluating how industrial heritage projects balance historical authenticity with functional innovation but also serve as a quantitative basis for optimizing policies and management mechanisms.

Table 3.3 Extracted and Transformed Elements from ICOMOS European Quality Principles

ICOMOS Core Principles	Transformed Elements
Knowledge	Management Communication, Accessibility
Public Interest	Collective Growth Capacity
Compatibility	Structural Compatibility
Minimal Intervention	Minimal Intervention Degree

ICOMOS Core Principles	Transformed Elements
Discernment	Intellectual Aggregation, Education Level
Sustainability	System Circularity
Good Governance	Process Participation (Autonomy)

Source: Compiled by the author based on original ICOMOS documents

（4）The Reference Value of the "National Industrial Heritage Management Measures" in International Case Evaluations

As a regulatory document formulated by China for the protection and utilization of industrial heritage, the National Industrial Heritage Management Measures still offer significant reference value in international case evaluations. This document systematically organizes the evaluation criteria for industrial heritage, emphasizing key aspects such as historical value, technological value, social value, authenticity, integrity, and continuity.

Although these standards were developed within the Chinese industrial heritage management framework, their core logic aligns closely with international standards. Therefore, in the element extraction process of this study, historical and technological heritage, industrial upgrading potential, management model innovation, and policy support have been identified as supplementary elements. These indicators not only assist in assessing the long-term viability of industrial heritage but also provide valuable insights for cross-national comparisons and benchmarking analyses.

Table 3.4 Evaluation Indicators from the National Industrial Heritage Management Measures

Primary Indicators	Secondary Indicators	Specific Content
Heritage Value	Historical Value	Witnessed the emergence of the industry in China or globally
		Played a significant role in advancing China's industrialization process
		Closely associated with important historical events or figures

Primary Indicators	Secondary Indicators	Specific Content
	Technological Value	Related to major projects such as the Self-Strengthening Movement, national capitalist industry and commerce, the "156 Projects," and the "Third Front Construction"
		Features innovation, significance, or uniqueness in technology or craftsmanship
		Had a substantial impact on the industry's development process
	Social Value	Had a profound impact on socio-economic and cultural changes
		Formed influential industrial spirit, production systems, or corporate culture
		Reflects the characteristics and social aspects of industrial production and related community life in its era
	Artistic Value	Industrial landscapes formed by production or living facilities possess strong uniqueness or representativeness
		Facilities, equipment, structures, or products strongly represent a particular production technique or enterprise
Preservation Status	Authenticity	Written records describing the heritage value are generally reliable
		The overall layout, core items, construction, reconstruction, restoration, and preservation status have relatively credible documentation and presentation
	Integrity	Maintains a high degree of completeness, allowing for a comprehensive representation of characteristic production layouts, production processes, or related living conditions through existing core items
Management Level	Continuity	Protection and utilization plans align with the heritage's characteristics and are practical
		Protection and utilization management systems and measures are clearly defined and effectively implemented
	Relevance	Protection and utilization have already, or are expected to, generate sustainable social and economic benefits

Source: Compiled by the author based on original National Industrial Heritage Management Measures documents

3.1.3 Element Screening and Integration

To ensure the scientific rigor and practical applicability of the extracted elements, this study follows a systematic screening and integration process through the following steps:

（1）Relevance Screening

Relevance screening is the primary step in the element extraction process, aiming to ensure a high degree of alignment between the extracted elements and the research objectives of industrial heritage transformation. Given that the core focus of industrial heritage transformation is protection and adaptive reuse, this study conducts a relevance assessment of all potential elements derived from the reference documents. Specifically, the screening process follows these key principles:

Direct Impact on Transformation Practices – Priority is given to elements that directly influence core transformation objectives such as industrial heritage protection, functional adaptation, social integration, and ecological restoration. For example, environmental sustainability, cultural value preservation, and social participation are retained as essential elements.

Exclusion of Weakly Related Content – Elements that are weakly associated with industrial heritage transformation or exclusively applicable to other types of heritage (e.g., natural heritage or intangible cultural heritage) are excluded from the research framework.

Alignment with Industrial Characteristics – Given that industrial heritage has distinct functional and technological attributes, the extracted elements must fully consider its role in economic development, technological innovation, and production space transformation.

Through this screening process, the final set of extracted elements remains highly relevant to the practical demands of industrial heritage transformation, providing a strong theoretical and practical foundation for constructing a comprehensive element system.

（2）Multidimensional Screening

The multidimensional screening process ensures that the extracted element framework comprehensively covers the economic, social, cultural, and environmental dimensions involved in industrial heritage transformation, while also emphasizing the interactions and synergies among elements within each category. The specific screening process includes the following aspects:

Comprehensive Dimension Coverage – Elements from the reference documents are categorized according to their potential dimensions, ensuring that each dimension (economic, social, cultural, and environmental) is represented by key elements.

Interaction Analysis – Within each individual category, elements are assessed for their potential interactions with elements from other categories. This process ensures that extracted elements are not only significant on their own but also have the potential for synergistic effects in the transformation process.

Avoiding Category Imbalance – Industrial heritage transformation is a multidisciplinary and cross-sectoral endeavor. Thus, the element extraction process strictly avoids overemphasizing a single category to ensure a balanced distribution across different dimensions.

Through multidimensional screening, the final element system comprehensively reflects the complexity and integrative nature of industrial heritage transformation, providing a robust foundation for collaborative evaluation across multiple layers.

（3）Operability Screening

The operability screening process ensures that the extracted elements possess practical feasibility, providing a clear and quantifiable basis for subsequent collaborative evaluation and strategy formulation. This process follows three key principles:

Clarity of Evaluation Standards – Priority is given to elements that have clear evaluation criteria, whether quantitative (e.g., carbon emissions, economic output) or qualitative (e.g., community participation level, cultural heritage transmission). Elements that are too vague or abstract are excluded from the final framework.

Support from Practical Experience – Selected elements must have been empirically validated through previous heritage conservation and adaptive reuse projects, ensuring that they hold practical reference value in industrial heritage transformation.

Balance between Operability and Adaptability – The elements must be applicable across different regions and project contexts, ensuring that they not only have clear implementation methodologies but are also flexible enough to be adapted to diverse practical scenarios.

Through extraction and screening, a multi-dimensional element matrix has been established, laying a solid foundation for constructing the industrial heritage transformation element system.

3.2 Evaluation Dimension Classification

After extracting the reference elements, this study systematically categorizes their attributes and functions using the Analytic Hierarchy Process (AHP) to construct a scientific framework for industrial heritage transformation. As a result, four evaluation dimensions have been established: Social Well-being, Economic Development, Environmental Sustainability, and Cultural & Social Governance. Each dimension corresponds to a core objective of industrial heritage transformation, covering the social, economic, ecological, and cultural impacts. This classification method ensures the scientific rigor and systematic structure of the evaluation framework while providing a solid theoretical basis for subsequent collaborative assessments.

3.2.1 Social Well-being Dimension

The Social Well-being Dimension focuses on the enhancement of overall societal welfare through industrial heritage transformation. It assesses how transformation projects improve residents' quality of life, promote social equity, and strengthen community well-being. The key extracted elements in this dimension include health, education, employment opportunities, safety, and subjective well-being. These indicators reflect both the positive structural changes that industrial heritage transformation brings to society and its capacity for optimizing and redistributing public resources.

Health and education serve as fundamental indicators of social well-being. In the process of industrial heritage transformation, improvements in public health infrastructure, enhanced healthcare services, and expanded educational resources contribute directly to the long-term development of communities. Employment opportunities are another crucial component of social well-being, as industrial heritage transformation often stimulates emerging industries, creates new job positions, and enhances residents' economic stability and social security.

Additionally, safety issues are integrated into the evaluation framework to assess how transformed spaces reduce safety hazards, optimize public space management, and enhance the overall livability of the social environment. Subjective well-being is considered a comprehensive indicator reflecting residents' social identity, sense of belonging, and overall quality of life improvements resulting from industrial heritage transformation. These elements collectively ensure that the Social Well-being Dimension provides a holistic evaluation of industrial heritage transformation's impact on societal welfare.

3.2.2 Economic Development Dimension

The Economic Development Dimension primarily examines how industrial heritage transformation contributes to regional economic restructuring, industrial upgrading, and economic growth. This dimension encompasses asset management, investment strategies, economic added value, cultural innovation, and service industry development. These indicators help assess how the adaptive reuse of industrial heritage promotes urban economic diversification, enhances regional market attractiveness, and generates new commercial and employment opportunities.

Economic added value is the core indicator of this dimension, directly measuring the contribution of industrial heritage transformation to economic growth. By introducing innovative industries and facilitating industrial restructuring, transformed industrial heritage sites increase the economic value of land and buildings, stimulate related industries, and create new economic growth drivers.

Investment strategy determines the sustainability and economic stability of industrial heritage reuse projects. A well-structured investment approach can attract private capital, enhance the market competitiveness of transformation projects, and ensure long-term financial returns.

Moreover, cultural innovation and service industry development are crucial aspects of the economic impact of industrial heritage transformation. Many industrial heritage sites are redeveloped into cultural and creative industry hubs, technology incubators, or mixed-use commercial complexes. These new functions not only increase the economic value of heritage assets but also drive regional cultural industries and service sector growth. Cultural innovation attracts creative talent and enterprises, strengthening local cultural branding, while service sector diversification enhances overall urban economic vitality.

These elements together construct the evaluation framework for the Economic Development Dimension, providing a scientific foundation for understanding the economic role and impact of industrial heritage transformation.

3.2.3 Environmental Sustainability Dimension

The Environmental Sustainability Dimension aims to assess the ecological impact of industrial heritage transformation, evaluating how projects contribute to natural resource conservation, pollution reduction, and optimized resource utilization. The key factors within this dimension include energy efficiency, system efficiency, cultural compatibility, interdisciplinary collaboration, technological tool application, and environmental awareness. These elements ensure that industrial heritage transformation aligns with both environmental protection and urban development objectives.

Energy efficiency and system efficiency serve as the core elements for evaluating the environmental sustainability of industrial heritage projects. These indicators assess whether retrofitted buildings and infrastructure meet energy efficiency standards, incorporate renewable energy technologies, and successfully reduce carbon emissions and resource consumption.

Additionally, cultural compatibility is a significant consideration, reflecting how industrial heritage aligns with the local cultural landscape during ecological transformation. This ensures that heritage sites retain their cultural identity and are not stripped of their historical significance due to overly aggressive environmental modifications.

Interdisciplinary collaboration is essential for environmental sustainability, as industrial heritage transformation involves architecture, environmental science, urban planning, and economics, among other fields. Through cross-disciplinary integration, it becomes possible to enhance ecological restoration strategies, improving both scientific rigor and practical feasibility.

Moreover, the application of technological tools—such as GIS spatial analysis and BIM (Building Information Modeling)—provides data-driven insights for assessing environmental impact. These tools enhance the precision and efficiency of sustainability evaluations.

Lastly, raising environmental awareness is a key objective of industrial heritage transformation. Through public education and community engagement, projects can foster a greater societal understanding of environmental sustainability, ensuring broader public support for transformation initiatives.

3.2.4 Cultural and Social Governance Dimension

The Cultural and Social Governance Dimension primarily focuses on cultural preservation, social engagement, and governance model innovation in the transformation of industrial heritage. This dimension includes multi-stakeholder participation, community identity, and community engagement, emphasizing how effective governance models can enhance cultural identity, strengthen community cohesion, and ensure the sustainable operation of transformation projects.

The multi-stakeholder participation mechanism is a core issue in industrial heritage preservation and adaptive reuse, involving cooperation between government entities, enterprises, academic institutions, social organizations, and local communities. A well-structured multi-level governance model ensures that projects receive continuous support throughout different phases while balancing the interests of various stakeholders, ultimately achieving a mutually beneficial outcome.

Community identity reflects how industrial heritage transformation enhances residents' sense of belonging through cultural activities, local branding efforts, and historical narratives. By integrating heritage sites into the cultural and social fabric of the community, these projects help reinforce historical continuity and collective memory, making industrial heritage an integral part of local cultural identity.

Community engagement serves as a key indicator of social governance capacity. Industrial heritage reuse projects should not be isolated from the surrounding community; rather, active involvement of local residents in planning, decision-making, and management fosters public acceptance and long-term sustainability. Encouraging community participation in governance ensures that industrial heritage sites remain socially and economically viable, while also preserving their historical and cultural significance. A well-structured governance model can further promote the long-term functionality of industrial heritage sites, ensuring that they contribute to both cultural preservation and broader socio-economic benefits.

3.3 Element System Integration

After identifying the core elements and classifying them into different dimensions, the next step involves the systematic integration of these elements to establish a comprehensive and coordinated evaluation framework. The goal of element system integration is to logically structure the four dimensions—social well-being, economic development, environmental sustainability, and cultural & social governance—ensuring that the selected elements can interact synergistically within the evaluation process, thereby providing a scientific and holistic assessment tool.

The integration process is not only based on the detailed analysis of each dimension but also requires proper categorization and weight distribution of the elements. This ensures that each component finds its logical position within the overall system and effectively contributes to the transformation objectives. To further clarify the relationships and functions of various elements, the following section will present a comprehensive element system table. Table 3.5 lists all reference elements, systematically categorized according to the previously defined evaluation dimensions.

Table 3.5 Collaborative Evaluation System for Industrial Heritage Transformation

Dimension	Aspect	Criterion	Element	Interpretation
A1 Social Well-being	B01 Health	C01 Physical Health	D01 Cleanliness and Health	Improvement in cleanliness and health conditions in the area
		C02 Mental Health	D02 Cultural Well-being	Enhancement of visitors' psychological well-being through participation in cultural activities
	B02 Knowledge & Education	C03 Intelligence	D03 Intellectual Concentration	Increase in intellectual capital through activation/enhancement of innovation and skills related to planned conservation
			D04 Education Level	Improvement in education levels of residents and visitors
		C04 Knowledge	D05 Management Communication	Enhancement of communication, dissemination, and transfer of design and management skills
			D06 Accessibility	Improved physical and intellectual accessibility of heritage sites
	B03 Work-Life Balance	C05 Employment Opportunities	D07 Employment Rate	Creation of new jobs (direct, indirect, and induced)
	B04 Safety	C06 Security	D08 Regional Safety	Improvement in safety within the area
	B05 Subjective Well-being	C07 Subjective Well-being	D09 Subjective Happiness	Improvement in user/visitor subjective happiness related to transformation
A2 Economic Development	B06 Economic Well-being	C08 Assets	D10 Economic Self-sufficiency	Increased sustainability of assets during management phase
		C09 Strategy	D11 Strategic Management Integrity	Long-term management strategies in place after project completion
		C10 Investment	D12 Investment Attraction	Attraction of funding sources for transformation (private capital, crowdfunding, tax incentives)
			D13 Reinvestment Participation	Reinvestment of profits into social impact initiatives
		C11 Added Value	D14 Population Activity	Increase in number of visitors and residents

Dimension	Aspect	Criterion	Element	Interpretation
			D15 Real Estate Value	Growth in real estate value and income from activities (construction, cultural industries, tourism, commerce, etc.)
			D16 Job Creation Impact	Creation of new jobs (direct, indirect, induced)
	B07 Research & Innovation	C12 Cultural Innovation	D17 Project Innovation	Activation of new projects in the space after resource reuse
			D18 Cultural Activity	Increase in cultural events and activities
	B08 Service Quality	C13 Service Sector	D19 Service Industry Activity	Increase in services available in the area (health, social welfare, utilities, transportation)
A3 Environmental Sustainability	B09 Environment	C14 Energy Efficiency	D20 Construction & Material Efficiency	Minimization of resource consumption (use of local, bio-eco-friendly, or recycled materials) and sustainable management of construction sites
			D21 Energy Saving	Increased energy efficiency (improved energy ratings, renewable energy, energy-saving systems, regulatory advancements)
		C15 System Efficiency	D22 System Circularity	Reduction of linear processes/transition to circular processes, with nature-based solutions
	B10 Landscape & Cultural Heritage	C16 Cultural Compatibility	D23 Structural Compatibility	Preservation of historical, architectural, and artistic value through new uses
			D24 Minimization of Intervention	Minimization of interventions related to transformation
			D25 Reversibility	Maximization of intervention reversibility in transformation
		C17 Multidisciplinary Approach	D26 Multidisciplinary Collaboration	Expansion of asset knowledge research from a multidisciplinary perspective (independent work across fields)
			D27 Interdisciplinary Collaboration	Cooperation across disciplines to achieve common goals

Dimension	Aspect	Criterion	Element	Interpretation
			D28 Transdisciplinary Collaboration	Integration of formal and informal knowledge and experiences to achieve common goals
		C18 Tools	D29 Planning Tool Application	Adoption of tools that facilitate asset intervention planning
		C19 Heritage Awareness	D30 Heritage Awareness Level	Enhancement of public awareness regarding architectural heritage and social well-being
A4 Cultural & Social Governance	B11 Politics & Institutions	C20 Stakeholder Engagement	D31 Multi-level Participation (Local)	Establishment of horizontal links between informal networks (individual groups, communities) and/or formal institutions (departments, policy groups) to influence the local living environment
			D32 Multi-level Participation (Intergovernmental)	Establishment of connections between informal networks and/or formal institutions (e.g., city with regional authorities, local research with international programs) to promote initiatives beyond their local scale (regional, national, etc.)
			D33 Multi-level Participation (Global)	Creation of connections between networks and/or (inter)governmental institutions that share similar objectives, aiming for ecosystem-wide future impacts
	B12 Social Relations	C21 Community Identity	D34 Identity Recognition	Increase in location identity/sense of place associated with transformation
			D35 Social Inclusion	Enhancement of social inclusivity (minority groups, migrants, and other vulnerable populations)
			D36 Collective Growth Capacity	Creation/enhancement of new ways of communal living based on solidarity, cooperation, and awareness of discrimination and injustice
		C22 Community Engagement	D37 Community Collaboration Level	Creation/enhancement of an active civil society during project governance

Dimension	Aspect	Criterion	Element	Interpretation
			D38 Process Participation (Consultation)	Stakeholder involvement in information, dialogue, and consultation phases
			D39 Process Participation (Co-creation)	Stakeholder participation in co-creation phase
			D40 Process Participation (Self-governance)	Stakeholder participation in self-governance phase

Source: Compiled by the author based on relevant original documents.

3.4 Universality of the Element System

The industrial heritage transformation element system constructed in this study is based on multiple authoritative documents from different countries, regions, and governance levels. These documents encompass policy regulations, industrial development, cultural preservation, and environmental governance, integrating frameworks from Italy's industrial heritage management, China's national policies, European Union-level cultural heritage protection principles, and international guidelines from the International Council on Monuments and Sites (ICOMOS). As a result, the element system possesses cross-cultural and cross-regional applicability, providing an operational theoretical basis for industrial heritage transformation in diverse contexts.

Although this study primarily focuses on industrial heritage projects in Turin, Italy, the development of the element system extensively references experiences from different countries and regions while comparatively analyzing various industrial heritage transformation models. Consequently, this theoretical framework is not only applicable to Turin's industrial heritage transformation practices but also serves as a scientific assessment tool and decision-making aid for industrial heritage projects worldwide. Despite variations in policy orientation, economic development levels, and socio-cultural backgrounds, the core objectives of industrial heritage transformation consistently revolve around historical preservation, functional renewal, industrial adaptability, environmental sustainability, social participation, and cultural identity. By extracting representative and universal key elements and integrating interdisciplinary analysis, this element system is designed to accommodate the flexible demands of different urban renewal needs.

Furthermore, as cultural heritage protection and urban revitalization efforts continue to develop globally, industrial heritage transformation practices increasingly align with internationalization and standardization trends. For instance, while Europe has a long tradition of industrial heritage conservation, Asian countries emphasize functional reuse and socio-economic benefits, whereas North America predominantly adopts market-driven industrial heritage redevelopment models. The element system proposed in this study can adapt to various policy environments and social contexts. By adjusting element weights and assessment criteria, the framework provides a highly adaptable and scalable analytical model for industrial heritage transformation worldwide.

Since the construction of this element system is based on multi-tiered, multidisciplinary, and cross-national experiences, it is not confined to a specific geographical, cultural, or industrial context. Instead, it demonstrates strong universality and adaptability, effectively addressing challenges encountered in different regions during industrial heritage protection and transformation. For example, in traditional industrial cities dominated by manufacturing, the system can aid in balancing heritage preservation with economic transformation. In contrast, in areas where urban renewal is driven by the cultural and creative industries, the system can evaluate the impact of heritage transformation on the cultural industry ecosystem. Under the framework of globalization and the United Nations' Sustainable Development Goals (SDGs), this element system provides decision-making support for local governments, planning institutions, investors, and researchers while also fostering knowledge sharing and cross-regional cooperation in industrial heritage protection.

In conclusion, the industrial heritage transformation element system proposed in this study is not only locally adaptable but also exhibits broad international applicability. Its theoretical framework and assessment system offer a systematic analytical tool for industrial heritage preservation and adaptive reuse in various regions. Moreover, it contributes to the global advancement of more scientific, rational, and sustainable industrial heritage management and transformation practices.

4 The Spatial Structure and Development Background of Turin’s Industrial Heritage Transformation

4.1 Development Background of Turin’s Industrial Heritage Transformation

As one of the most representative industrial cities in Italy, Turin embodies the evolution of European modern industrialization through its industrial structure and urban form. From the initial wave of industrialization in the late 19th century to the postwar "golden age" and the subsequent decline and restructuring at the end of the 20th century, Turin’s development has not only mirrored the rise and fall of industrial giants such as FIAT, but also reflected broader global trends in the shift of manufacturing hubs and the transformation of urban functions.

Table 4.1 Industrial Development Trajectory of Turin

Phase	Period	Main Characteristics	Key Events / Representative Institutions
Industrial Initiation and Rise of FIAT	Late 19th – Early 20th Century	Infrastructure and railway development; emergence of an industrial system. In 1899, FIAT was founded, marking the start of the automotive era.	Establishment of FIAT (1899), completion of Lingotto Factory (1923), emergence of Lancia, Ansaldo, etc.
Industrial Expansion and “Golden Age”	Post-WWII – 1970s	Postwar recovery and Marshall Plan fueled industrial boom; integrated supply chains developed; rapid urban and population growth.	Boom of FIAT 500, expansion of Mirafiori Plant, population growth of nearly 60% from 1951 to 1971
Industrial Decline and Restructuring	1980s – Early 21st Century	Global competition, oil crises, and outsourcing led to decline; urban renewal and economic restructuring launched by local government.	Spina Centrale Plan (1995), 2006 Winter Olympics, revitalization of OGR industrial site

Source: Compiled by the author

4.1.1 The Industrial Development History of Turin

（1）Late 19th Century to Early 20th Century: The Beginning of Industrialization and the Rise of Fiat

In the mid-19th century, with the deepening of the European Industrial Revolution, Turin gradually developed into one of Italy's key industrial centers. Following the unification of Italy in 1861, Turin briefly served as the nation's capital, a political status that facilitated urban infrastructure development, particularly in transportation. The expansion of the railway network positioned Turin as a national transportation hub. From the 1870s onward, industries such as mechanical manufacturing, textiles, and metal processing experienced rapid growth, forming a comprehensive industrial system. Thanks to its advantageous geographical location, Turin attracted substantial capital and labor, solidifying its critical role in Italy's industrialization process.

Additionally, Turin's industrialization was bolstered by government policies supporting mechanical manufacturing. In the late 19th century, the Italian government encouraged technology imports and domestic production, spurring the rapid expansion of Turin's mechanical industry. A number of manufacturing enterprises, including Ansaldo and Lancia, emerged during this period, leading advancements in locomotive production, steam-powered machinery, and precision mechanical engineering. Simultaneously, a series of industrial training schools were established to cultivate skilled workers and engineers, ensuring a stable talent pool for the city's industrial sector.

On a socio-economic level, industrialization led to a dramatic population surge. Between the 1870s and 1890s, Turin's population increased significantly as rural migrants flocked to the city to work in factories, fostering the development of working-class communities. Numerous workers' housing districts emerged around industrial zones, gradually shaping Turin's spatial structure into that of an industrial city. Additionally, financial institutions and trade organizations rapidly developed, further cementing Turin's role as Italy's industrial and economic hub.

By the late 19th century, the European automobile industry was emerging, and small-scale automobile manufacturing enterprises began to appear in Italy. In 1899, Giovanni Agnelli and other investors founded Fabbrica Italiana Automobili Torino (FIAT) in Turin, marking the city's official entry into the modern automotive industry. Initially, Fiat's annual production was relatively small, but through its innovative manufacturing techniques and precise market positioning, the company quickly gained prominence in both domestic and international markets. As Fiat expanded, Turin's industrial landscape began to transform, with the automobile industry gradually becoming the dominant sector and attracting numerous supporting enterprises.

Entering the 20th century, Fiat continued to expand its production capacity and, in 1916, initiated the construction of the Lingotto Factory, which was completed in 1923. This factory became one of the most advanced automobile manufacturing plants in the world at the time. It employed an assembly line production model, significantly increasing automobile output and manufacturing efficiency. Additionally, the factory's rooftop test track, an innovative architectural design, exemplified the modernist approach to industrial building design. With Fiat's remarkable success, Turin's automotive industry chain became more sophisticated, driving the growth of mechanical engineering, metal processing, chemical production, and rubber manufacturing. By the early 20th century, Turin had firmly established itself as Italy's most important industrial city.

（2）Post-WWII to the 1970s: Industrial Expansion and Turin's "Golden Era"

After World War II, Italy entered a period of post-war reconstruction and economic recovery, during which Turin, as an industrial powerhouse, benefited from government economic revitalization policies and financial support from the Marshall Plan. As a key driver of Italy's industrial resurgence, Fiat not only quickly restored its pre-war production capacity but also experienced unprecedented expansion from the 1950s to the 1970s, becoming a symbol of Italy's economic growth.

During this period, Fiat dominated the domestic market while aggressively expanding internationally, positioning Turin as a global automobile manufacturing hub. In the 1950s, Fiat introduced several bestselling models, with the Fiat 500 becoming one of the most popular post-war compact cars in Italy. It symbolized the modernization of Italian society and the rise of personal mobility. Fiat's adoption of large-scale assembly line production significantly increased manufacturing efficiency, enabling the company to supply both domestic and international markets. The surge in production led Fiat to capture a substantial share of the global market, cementing its status as a pillar of the European automobile industry.

Meanwhile, Turin's industrial infrastructure continued to expand, with large-scale industrial zones emerging around the city and evolving into highly integrated industrial clusters. The Mirafiori plant, initially completed in 1939, underwent extensive post-war expansion, becoming one of Europe's largest automobile manufacturing facilities and playing a crucial role in the modernization of Italian manufacturing. The rapid growth of the automobile industry also spurred the development of related sectors such as steel, chemicals, plastics, and electronics, forming a highly interconnected industrial network centered in Turin. This comprehensive industrial system provided a strong foundation for Italy's long-term economic growth.

This period also witnessed accelerated urbanization. A massive influx of labor, particularly migrants from southern Italy, fueled industrial growth. Between 1951 and 1971, Turin's population skyrocketed from 700,000 to 1.1 million, leading to rapid urban expansion. New residential districts, commercial centers, and social infrastructure were developed to accommodate the growing working-class population. Consequently, the city's spatial structure underwent significant changes, with industrial zones and workers' housing areas expanding rapidly, reinforcing Turin's economic model centered around the automobile industry. However, this heavy reliance on a single industry laid the groundwork for future economic vulnerabilities, leaving the city with limited flexibility and adaptability in the face of impending industrial transformations.

（3）1980s to Early 21st Century: Industrial Decline and Challenges of Transformation

Entering the 1980s, Turin's industrial development faced severe challenges, primarily due to intensifying global market competition, industrial relocation, economic recession, and the structural singularity of its economy. The global automotive market had entered a phase of multipolar competition, with German, Japanese, and American automakers rapidly rising to dominance through advanced manufacturing techniques, fuel efficiency, and stricter quality control measures. These developments significantly eroded Fiat's market share. Furthermore, the oil crises of 1973 and 1979 not only triggered global economic turbulence but also shifted consumer preferences toward fuel-efficient vehicles, leading to a sharp decline in demand for traditional high-displacement, fuel-intensive models. This change posed a substantial challenge to Fiat and other traditional European automakers.

To adapt to these market shifts, Fiat implemented a series of strategic adjustments. First, the company increased automation in its production processes to enhance efficiency and reduce labor costs, aiming to mitigate competitive pressures. However, this automation led to significant job losses, exacerbating unemployment in Turin. Second, Fiat gradually downsized its local manufacturing operations and relocated some production lines to southern Italy and Eastern European countries such as Poland and Serbia, where labor costs were lower. While this strategy helped reduce operational expenses, it resulted in a substantial loss of employment opportunities in Turin, severely impacting the city’s manufacturing-dependent economy.

By the early 1990s, Italy’s economy had entered a period of stagnation, with shrinking domestic demand and escalating global competition further worsening Turin’s industrial outlook. Fiat repeatedly implemented workforce reductions, causing unemployment rates in the city to surge and leading to economic decline in working-class communities. Large tracts of industrial land were abandoned or left idle, and formerly thriving industrial districts fell into decay. Some areas even experienced rising crime rates and urban poverty, accelerating the functional decline of the city.

Recognizing the need to break free from its overreliance on manufacturing, the Turin municipal government sought a new development model. In 1995, the city launched the "Spina Centrale" (Central Spine) project, aimed at revitalizing Turin through infrastructure upgrades, urban space redevelopment, and economic restructuring. Key initiatives included the demolition of abandoned railway facilities, the construction of a modern public transportation network to improve intra-city connectivity, and the introduction of high-tech industries and service sectors into former industrial zones to foster economic diversification. Simultaneously, the government increased investments in cultural industries and promoted cultural tourism, leveraging Turin’s rich historical and cultural resources to attract both domestic and international visitors.

The successful hosting of the 2006 Winter Olympics marked a pivotal moment in Turin’s transformation. The event spurred large-scale infrastructure improvements, including the construction of new transportation hubs and the enhancement of public spaces, while also elevating Turin’s international reputation. This shift accelerated the city’s evolution from a purely industrial hub to a multifunctional metropolis, integrating culture, tourism, and advanced manufacturing. Urban renewal projects were implemented citywide, with numerous abandoned industrial buildings repurposed into cultural and creative spaces, commercial complexes, and technology innovation centers. A notable example is the Officine Grandi Riparazioni (OGR), a former train repair facility successfully transformed into a vibrant cultural and innovation hub. This trend underscored the growing importance of industrial heritage reuse, providing a model for sustainable urban redevelopment.

Overall, Turin's industrial trajectory has encompassed early industrialization in the late 19th century, economic prosperity in the mid-20th century, followed by decline and restructuring in the late 20th century. The rise and fall of Fiat serve as both a microcosm of Turin's industrial history and a reflection of global manufacturing shifts. With the increasing recognition of industrial heritage preservation and the rise of the post-industrial economy, the key challenge now is how Turin can fully leverage its rich industrial legacy to achieve economic revitalization and sustainable urban transformation in the modern era.

4.1.2 The Spatial Distribution and Characteristics of Turin's Industrial Heritage

Turin's industrial heritage exhibits a rich historical layering, with its spatial distribution shaped by industrial development processes, urban planning, economic transformations, and societal shifts. The spatial organization of Turin's industrial heritage is characterized by a typical riverfront distribution, strong dependence on transportation networks, large-scale factory complexes, and highly concentrated industrial functions. These characteristics not only define the spatial morphology of industrial heritage but also determine the complexity and challenges of its subsequent transformation.

Table 4.2 Spatial Distribution and Characteristics of Industrial Heritage in Turin

Category	Spatial Distribution Characteristics	Summary Description
Industrial Clusters along Railway and Transport Corridors	Located near major railway lines; reliant on rail-based transportation	Factory siting depended on the railway logistics system, forming an integrated layout of efficient transport and production.
Industrial Belt along the Po River	Densely distributed along the Po River; dependent on hydraulic resources	Early industries relied on the Po River for power generation, cooling, and transportation; declined due to pollution and policy restrictions.
Industrial Clusters in Satellite Towns	Peripheral towns complemented the core city, forming a "core-periphery" structure	Urban industrial expansion gave rise to satellite industrial towns, reinforcing supply chain coordination; recent decline followed by transformation attempts.

Architectural Features and Redevelopment Potential	Robust structures, flexible spaces, large-span workshops with high windows and historical traces	High reuse potential; easily adaptable for creative, cultural, or educational functions; retain industrial memory elements such as chimneys and rail tracks.

Source: Compiled by the author

（1）Industrial Clusters Along Railways and Transportation Corridors

Turin's railway network expanded rapidly in the late 19th century, establishing the city as a major national transportation hub. The accessibility provided by railways directly influenced the siting of industrial zones, leading many large factories and manufacturing enterprises to be concentrated along major railway lines to ensure efficient transport of raw materials and distribution of products. For example, the OGR (Officine Grandi Riparazioni) railway repair workshop, a crucial maintenance center for the Italian railway system, was strategically located near a major railway line, serving as a national hub for locomotive repair and maintenance. Similarly, the Lingotto Factory, constructed by Fiat, leveraged the railway system to streamline automobile manufacturing and distribution, while the Mirafiori Factory further reinforced this model by establishing an integrated production and logistics system centered around railway transport.

By the early 20th century, rapid industrial development along the railway corridors attracted numerous supporting industries, including machinery manufacturing, chemical production, and rubber processing. These industries were directly linked to railway transportation, giving Turin's industrial production a higher degree of regional integration. However, with technological advancements and changes in production models, railway transport gradually lost its dominance to road freight, leading to the decline of some railway-based industrial zones. In the post-industrial era, these areas have become focal points for urban regeneration and adaptive reuse projects.

（2）Industrial Belt Along the Po River

The development of Turin's industries was profoundly influenced by the Po River, the longest river in Italy, which flows through the city and historically provided abundant water resources for industrial production. Between the 19th and mid-20th centuries, industries dependent on water resources, such as textile manufacturing, paper production, and machinery fabrication, were concentrated along the Po River. These factories not only relied on the river for hydroelectric power and cooling systems but also used it for goods transportation, making the Po River corridor one of Turin's earliest industrial clusters.

A notable example is the textile and paper mills along the Po River, which rapidly expanded in the early 20th century, creating a significant number of employment opportunities for the city. However, as industrial water consumption increased and environmental concerns grew, the government began imposing stricter regulations on these industries in the latter half of the 20th century, gradually pushing them toward technological upgrades or relocation. In recent years, several industrial heritage sites along the Po River have been repurposed into cultural spaces and ecological parks. For instance, some former factory buildings have been transformed into museums, exhibition halls, and public green spaces, providing new recreational areas for urban residents.

（3）Industrial Districts and Satellite Town Clusters

During the mid-20th century, as industrial production expanded, some of Turin's major industrial districts extended outward to the city's periphery, forming a network of satellite towns. These towns not only hosted parts of the manufacturing sector but also became key supply chain hubs for major enterprises like Fiat. For instance, Fiat's Rivalta Factory, located outside Turin, was a crucial component manufacturing base, while the Grugliasco district developed into a center for mechanical processing and plastic manufacturing, creating a complementary industrial cluster with Turin's urban core.

The emergence of these satellite towns contributed to the completion of Turin's industrial ecosystem, forming a "core-periphery" industrial distribution model. However, by the late 20th century, globalization and industrial relocation led some enterprises to move production abroad, causing economic downturns in certain satellite towns. In response, both the government and private sector have promoted industrial upgrading and the establishment of technology parks to revitalize these areas. For example, parts of the Rivalta Factory have been converted into research centers focusing on renewable energy and autonomous driving technology, fostering closer collaboration between Turin's universities, research institutes, and high-tech industries.

（4）Architectural Characteristics of Industrial Heritage

Turin's industrial heritage encompasses a diverse range of architectural typologies, from large-scale factory complexes to precision manufacturing facilities. These buildings exhibit distinct structural, spatial, and material characteristics that reflect different stages of industrial technological evolution.

From an architectural perspective, Turin's industrial heritage is predominantly characterized by large-span factory halls, reinforced concrete frame structures, and continuous production line layouts. These buildings typically feature vast open spaces and high-level skylights, which facilitated mechanized production processes. Additionally, several industrial sites have retained tall chimneys, underground conveyor systems, and dedicated railway tracks, which not only serve as remnants of past industrial activities but also provide valuable design elements for contemporary adaptive reuse projects.

A key example is the heavy industry heritage along the Dora River, which historically served as Turin's metal smelting, mechanical engineering, and power generation hub. In the early 20th century, multiple steel mills, foundries, and hydroelectric plants were established along the river to support Turin's industrialization. One of the most iconic sites is the Paracchi Textile Factory, which initially relied on the hydropower resources of the Dora River and gradually evolved into one of northern Italy's largest textile production centers. The factory's large-span steel frame structure provided high spatial flexibility, offering great potential for future functional repurposing.

The transformation of such sites not only enables the adaptive reuse of industrial heritage but also fosters spatial innovation and social identity reconstruction. Through precise urban regeneration strategies, these historical buildings have retained their industrial-era identity while adapting to the demands of contemporary urban economies. Consequently, Turin's industrial heritage has been reintegrated into the city's spatial fabric, playing an active role in its post-industrial urban development.

4.1.3 The Master Plan for Industrial Heritage Transformation: The "Spina Centrale" Project

Facing urban decline caused by industrial recession, Turin launched a new master plan in 1995, aiming to revitalize the city through transportation improvements and brownfield redevelopment. The core concept of this plan was the renowned "Spina Centrale" (Central Spine) Project, which sought to establish a new north-south development axis along the city's central axis.

The specific approach involved moving the original railway line—which previously ran through the city and divided it into two halves—underground, while constructing new urban avenues and public spaces at the surface level. This transformation physically reconnected the two sides of the city and used this central axis as a foundation to reshape

Turin’s urban identity.

The primary objective of the Spina Centrale Project was to preserve the unique value of the city's industrial heritage while improving urban spatial structure, optimizing land use patterns, and enhancing the city's overall competitiveness. This plan not only focused on the renewal of physical space but also emphasized functional integration, promoting the adaptation of industrial heritage to the demands of modern urban development, ultimately fostering a more sustainable and diversified urban structure.

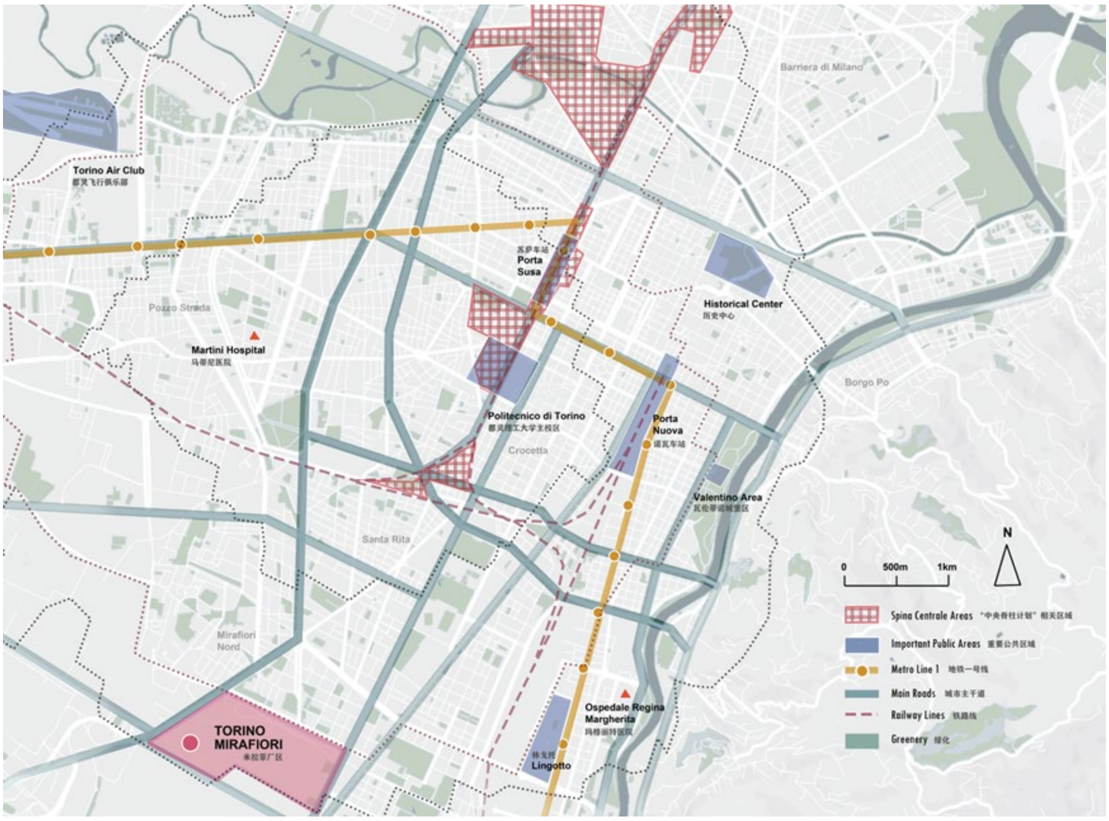


Figure 4.1 Turin's "Central Spine" Plan

Source: Drawn by the author based on official documents.

Along the Spina Centrale, the plan divides the redevelopment of former industrial land into four major sections (Spina 1-4): Spina 1 and 2 include the newly constructed multifunctional Porta Susa railway station, the large-scale former OGR railway repair facility, and Politecnico di Torino. Spina 3 and 4 encompass the extensive brownfields along the Dora River, including the redevelopment of the Michelin tire factory and former steel plants into Dora Park, as well as the Environmental Technology Park. By constructing new tree-lined boulevards and urban arterial roads, the Spina Centrale not only enhances north-south traffic accessibility but also creates redevelopment opportunities for the former industrial zones along its route.

The plan emphasizes mixed-use development, transforming former factory sites into libraries, theaters, office buildings, commercial areas, and government institutions while also implementing public space and community environment improvement programs to enhance the living conditions of the surrounding neighborhoods.

The implementation of the plan encompasses multiple dimensions. First, infrastructure renovation and optimization play a crucial role. To eliminate the isolation of industrial areas from the urban core and enhance connectivity between different districts, the plan upgrades the transportation network, including railway expansion, road improvements, and public transportation system enhancements. The optimization of urban transit and pedestrian networks, along with the strengthening of connections between the city and its surrounding areas, significantly improves urban mobility and provides better spatial conditions for industrial heritage reuse.

Second, commercial and residential development is an essential component of the plan. By constructing new commercial centers, office districts, and residential communities, the project aims to introduce new industries and residents, thereby increasing population density and stimulating economic vitality in the area. Additionally, the plan prioritizes the enhancement of public spaces and environmental quality by establishing parks, plazas, and green spaces, which help alleviate the pressure of high-density development during the industrial heritage transformation process, ultimately improving the overall livability of the city.

Beyond transportation and spatial layout optimization, the Spina Centrale plan introduces cultural and social development strategies to promote the integration of industrial heritage into urban life. Under this framework, several former industrial facilities have been repurposed as cultural, educational, artistic, and innovation hubs, fostering a vibrant cultural atmosphere and social dynamism. The plan also emphasizes multi-stakeholder participation, encouraging collaboration between the government, businesses, local communities, and academic institutions to ensure that industrial heritage reuse serves not only economic interests but also social equity and cultural identity.

In essence, the Spina Centrale plan has provided Turin with a multi-kilometer urban renewal corridor, linking several major industrial heritage redevelopment projects together, thereby forming the backbone and spatial framework of the city's revitalization. This strategy exemplifies the concept of using transportation corridors to drive land regeneration, transforming former infrastructure that once fragmented the city into a central axis connecting its different parts. On a macro spatial scale, this initiative has guided Turin's transition from a single-function industrial city to a diversified urban center.

After more than two decades of continuous implementation, the Spina Centrale has given rise to a series of exemplary industrial heritage transformation projects, successfully reshaping the city's spatial identity. These projects vary in character: some have converted large abandoned factories into cultural and commercial complexes, while others have repurposed brownfields into urban parks.

The following section will analyze three representative case studies—the Dora Industrial District (now Dora Park), the OGR Railway Repair Facility, and the Fiat Lingotto Factory—to explore their transformation models and innovations, summarizing the key lessons from Turin's industrial heritage redevelopment experience.

4.2 Typical Industrial Heritage Transformation Models and Case Studies

4.2.1 Brownfield Ecological Regeneration Model: The Transformation of the Dora River Industrial District

The Dora River Industrial District Redevelopment (Parco Dora) is a significant urban renewal project in Turin, aimed at transforming abandoned industrial land into public open spaces, embodying the harmonious integration of heritage preservation and modernization. This project not only provided Turin with a new urban green space but also demonstrated, on a broader level, how innovative design can be leveraged to protect and repurpose industrial sites, thereby fostering the sustainable development of cities.

Located in the northern part of central Turin, the Dora River Industrial District was once one of the city's key heavy industrial hubs. Since the early 20th century, major factories, including the Ferriere steel plant under Fiat and the Michelin tire factory, were established along the Dora River, shaping the industrialization of the river valley and making the area the industrial heart of the city. However, by the 1980s, with the decline of the steel and manufacturing industries, these factories gradually shut down, leaving behind large stretches of abandoned industrial land and a severely polluted environment in the northern part of the city. To heal this urban "scar," Turin launched the Urban

Redevelopment Program (PRIU) in 1998, designating the Dora River Industrial District as a key transformation area. Simultaneously, under the Spina Centrale Plan, urban planners divided the redevelopment area into multiple functional zones, with the Dora River Industrial District serving as a crucial component of the "Third Spine" project. Following the overall framework of the Spina Centrale, approximately 45 hectares of former brownfield land along the Dora River were redeveloped into an urban green space. Through an international design competition, the proposal by German landscape architect Peter Latz was selected. His winning design retained significant industrial relics while transforming the site into the unique urban park now known as Parco Dora.

The design of Parco Dora fully reflects the concept of "landscape regeneration within industrial heritage." The park is composed of five interconnected sections, each with distinct characteristics: Ingest, Vitali, and Michelin are named after the original factories that occupied these locations, preserving their respective industrial structures; the other two sections, Valdocco and Mortara, are located above newly constructed underground tunnels. The design preserved and repurposed several iconic industrial structures. In the Vitali zone, a large steel-framed factory hall (formerly a metal rolling and stripping workshop) was partially preserved, with sections of the roof and towering red steel columns left intact, creating a striking landmark at the park's center. The Michelin zone retained the cooling tower from the former Michelin factory, integrating it into the green landscape. In the Ingest zone, portions of the original steel plant's structural framework were preserved. Along the Dora River in the Valdocco zone, reinforced concrete supports were maintained to highlight the historical features of the industrial water channels. These industrial relics are interwoven with new lawns, forests, gardens, sports fields, and water features, while pathways and bridges connect the various zones, forming a continuous network of open spaces. The design team emphasized preserving the local identity of each zone while incorporating new landscape elements, allowing industrial remains to interact with the natural environment. This landscape renewal approach has been metaphorically described as a "string of pearls", where industrial structures act as historical jewels, threaded along the green axis of the Dora River. Since its completion, Parco Dora has significantly improved environmental quality, providing a 45-hectare urban green lung, while the preservation of industrial structures reinforces historical memory and community identity, strengthening residents' emotional attachment to what they now proudly call "our park."

The transformation of Parco Dora demonstrates significant innovation and exemplary value. First, it is a successful example of combining brownfield ecological remediation with industrial heritage conservation. Instead of simply clearing and rebuilding, the project retained industrial structures while remediating soil pollution and revitalizing the ecological system. Many of the former factory structures were repurposed for new public functions, such as sheltered event spaces and exhibition areas, creating a distinctive landscape experience. This approach follows the principles of the Landschaftspark Duisburg-Nord in Germany's Ruhr region while incorporating Turin's local cultural context and openness, balancing industrial aesthetics with inviting public spaces.

Second, the project successfully restructured urban functions. The Dora River industrial sites previously fragmented the urban landscape, limiting connectivity between surrounding neighborhoods. Today, Parco Dora reconnects newly developed residential areas and commercial centers, using green spaces and pedestrian pathways to enhance accessibility and social interaction. The park transformed a former industrial barrier into a social and recreational hub, boosting regional vibrancy and safety.

Third, the park's management model emphasizes public participation, frequently hosting community events, cultural festivals, and public activities, thereby enhancing social cohesion. These inclusive engagement strategies earned Parco Dora the 2018 European Garden Award, further establishing it as a benchmark for industrial brownfield regeneration.

In summary, the Dora River Industrial District has undergone a remarkable transformation, rising like a phoenix in the form of an ecological urban park. This project exemplifies the "industrial heritage + ecological landscape" transformation model. The success of this approach lies in respecting the site's history, preserving its memory while reshaping its environment, and achieving a harmonious balance of social, environmental, and aesthetic values.

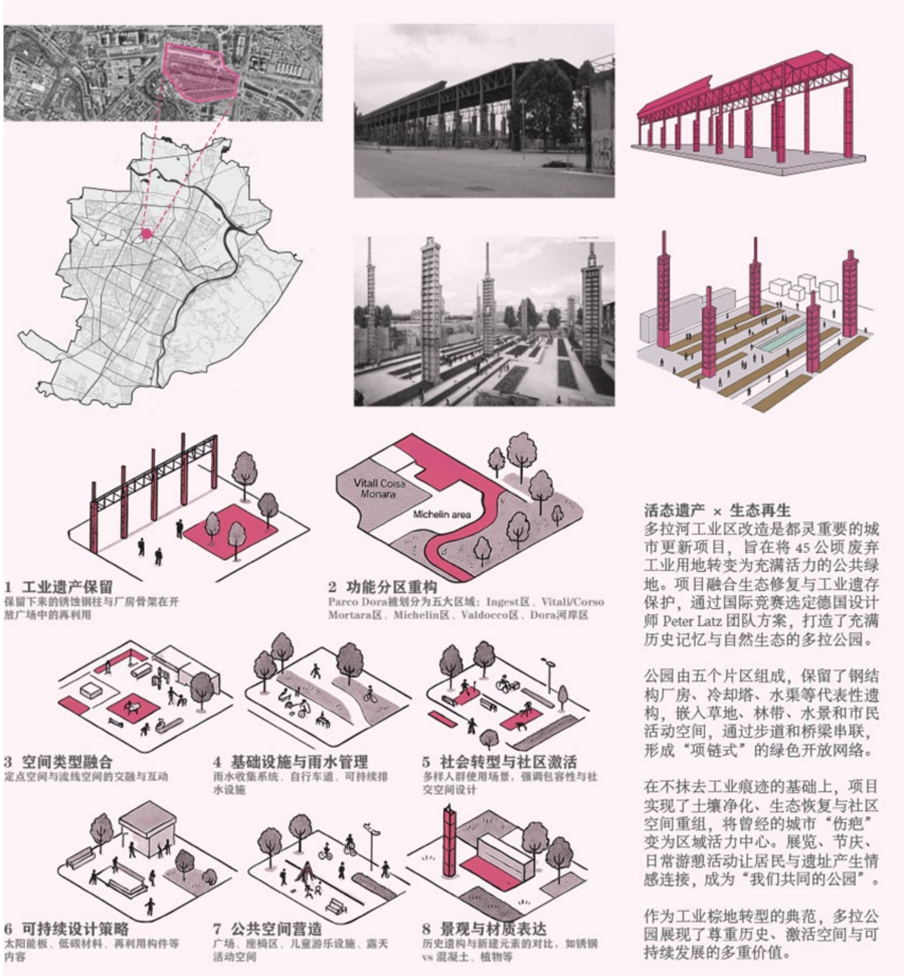


Figure 4.2 Dora River Industrial Area Before and After Renovation

Source: Drawn by the author based on official documents.

4.2.2 Cultural and Creative Industry Integration Model: OGR Workshop Redevelopment

OGR (Officine Grandi Riparazioni) was once a vast railway vehicle maintenance facility in the center of Turin, built between 1885 and 1895. Its hundred-meter-long vaulted workshops are outstanding examples of 19th-century industrial architecture. For nearly a century, OGR served as a key maintenance hub for the Italian National Railway, playing a crucial role in Turin’s industrial development. However, with advancements in railway technology and changes in production models, OGR gradually lost its original function and finally ceased operations in 1992. The facility remained abandoned for years, turning into an urban dead zone. Entering the 21st century, the Turin municipal government, along with various foundations, began promoting the repurposing of OGR. The transformation plan gradually took shape, with the goal of turning the facility into a

21st-century hub for culture and innovation, serving both urban cultural life and technology-driven industries.

During the redevelopment process, the dual approach of preservation and renewal became the core principle of OGR's transformation. The historic 200-meter-long workshop buildings, with their brick walls and cast-iron roof trusses, were entirely preserved and structurally reinforced, allowing them to be repurposed with new functions. On one hand, the large-scale indoor space was redesigned into contemporary art galleries, performance venues, and event spaces. Since its reopening in 2017, OGR has hosted major installation art exhibitions, concerts, and theater performances, featuring internationally renowned artists and groups such as William Kentridge and New Order, cementing its status as a new cultural landmark in Turin. On the other hand, a separate section of OGR was converted into a technology research and startup incubation center. In 2019, a "Tech Accelerator Zone" was established within the former workshop space, attracting corporate partners such as Microsoft, providing workspace and laboratory facilities for startups. As a result, OGR became one of the few hybrid "arts + technology" innovation hubs in Europe.

From an architectural perspective, the renovation team retained the industrial character of the hall's steel beams, cranes, and other structural elements, while integrating glass curtain walls, modern lighting, and digital infrastructure, creating a striking contrast between history and modernity. After nearly 1,000 days of renovation and an investment of over 100 million euros, this massive facility was finally revitalized, officially opening to the public in 2017. Within its first two years, OGR attracted over 500,000 visitors, demonstrating its broad public appeal. With the launch of the "Tech District" in June 2019, OGR successfully implemented a dual-track model of culture and technology, achieving full-scale operation.

The OGR transformation represents a highly innovative and exemplary model. In terms of redevelopment strategy, it embodies a culture-led approach to industrial integration: first activating the space with cultural programs, then introducing technology-driven industries to ensure long-term sustainability. As a cultural space, OGR revitalized the area by hosting avant-garde art exhibitions and music performances, attracting large numbers of visitors and reinvigorating the local community. As an innovation space, it established startup incubators and research collaboration hubs, drawing entrepreneurs and tech professionals. This dual-functional model of "culture +

technology" positioned OGR as one of Turin’s creative economy engines, demonstrating the potential of industrial heritage to serve as an incubator for new industries.

Additionally, the OGR redevelopment stands out as a successful example of multi-stakeholder collaboration. The project was jointly undertaken by the municipal government, non-profit foundations (such as the CRT Foundation), and private enterprises, ensuring synergistic funding, operation, and resource allocation. The government provided planning support, the foundation led investment and operational management, while private firms and academic institutions contributed innovation resources, forming a public-private partnership (PPP) governance model. This coordinated governance framework serves as a valuable reference for large-scale industrial building renovations.

Furthermore, OGR’s redevelopment strategically integrates into Turin’s urban network. Geographically, it is adjacent to the Polytechnic University of Turin and the newly built Porta Susa railway station. Functionally, it is linked with nearby industrial parks and cultural institutions, amplifying its overall impact.

Ultimately, OGR evolved from a single-purpose railway workshop into a multifunctional urban hub for culture and innovation, representing a comprehensive transformation model for industrial heritage sites. Its innovation lies in function mixing and industrial upgrading, whereby cultural programming and technological investment breathe new life into a century-old industrial site, making it a driving force for Turin’s economic transformation.

Figure 4.3 OGR Train Maintenance Workshop Before and After Renovation

Source: Drawn by the author based on official documents.

4.2.3 Mixed-Use Complex Redevelopment Model: The Transformation of Lingotto Factory

Lingotto Factory stands as one of the most symbolic cases of industrial heritage transformation in Turin. Built in 1923 as a large-scale automobile assembly plant for FIAT, it was designed by engineer Matté Trucco and became renowned for its unique spiral ramp and rooftop test track. This five-story, 500-meter-long reinforced concrete building was hailed as a masterpiece of modern architecture at the time, representing the pinnacle of Fordist assembly line production. However, by the 1980s, shifts in manufacturing models and changing urban land-use demands led to the factory ceasing production in 1982. Faced with the challenge of repurposing such a vast and historically significant industrial complex, FIAT launched an international design competition in 1984, aiming to revitalize the structure while preserving its architectural identity and historical significance. Ultimately, the renowned architect Renzo Piano and his studio won the competition and began the redevelopment process in 1985. The project was driven by two key objectives: reviving this iconic building by giving it new functions and ensuring that its architectural legacy remained an integral part of the city’s memory.

The renovation of Lingotto was carried out in phases throughout the 1990s, resulting in a remarkable transformation. The repurposed complex was converted into a large-scale multifunctional urban hub, integrating commercial, cultural, and educational facilities. The interior was reorganized to accommodate a shopping mall, a convention and exhibition center, office spaces, hotels, and a new engineering school affiliated with the Polytechnic University of Turin. The famous rooftop test track was preserved rather than demolished, with new additions including a glass-domed auditorium—the renowned “Lingotto Oval Hall”—and a rooftop garden, breathing new life into the elevated space. Throughout the redevelopment, Renzo Piano’s team adhered to a strategy of preserving the building’s exterior while extensively reconfiguring its interior layout. The street-facing façade and overall massing of the structure remained virtually unchanged, ensuring the architectural integrity of this modernist landmark. Meanwhile, the interiors were restructured using contemporary design techniques to accommodate new functions. For example, the former assembly line space was transformed into a shopping gallery and exhibition area, while a newly added spiral pathway at one end of the factory allowed visitors to ascend directly to the rooftop, seamlessly connecting different levels and functions. This approach of “preserving the exterior while reconstructing the interior” has since been recognized as a benchmark for adaptive reuse of industrial buildings.

The transformation of Lingotto is particularly significant because it pioneered the shift from an industrial manufacturing site to a modern service-oriented complex. As one of the earliest large-scale industrial reuse projects completed in the late 20th century, its success has served as a model worldwide, demonstrating that an aging factory can be revitalized into a contemporary urban space through high-quality design while ensuring economic sustainability. For instance, the introduction of a shopping center and convention facilities stimulated commercial development in the surrounding area, while the integration of university functions injected academic and innovation resources into the site. The inclusion of hotels and office spaces further supported Turin’s business environment, making Lingotto one of the city’s new sub-centers and attracting foot traffic and employment back to what was once a declining industrial zone.

At the same time, the redevelopment upheld the principle of industrial cultural preservation. The retention of the iconic spiral ramp and rooftop test track, along with the establishment of the FIAT Gallery to showcase the history of the automobile industry, allowed the site to maintain its industrial identity, enabling visitors to engage with Turin's manufacturing heritage even in its repurposed form. Lingotto also exemplifies a model of industrial heritage renewal led by private enterprises. As the site's owner, FIAT took the initiative to enhance the asset's value through adaptive reuse, marking its transition from a manufacturing entity to an urban developer and operator. This offers a valuable reference for how private-sector involvement can contribute to the conservation and revitalization of industrial heritage.

In conclusion, the transformation of Lingotto Factory epitomizes a "protective redevelopment" model, where top-tier design solutions have converted an industrial building into a modern service hub with minimal alterations to its external appearance while achieving maximum functional adaptation. This approach successfully balances economic viability with cultural preservation, setting a precedent for industrial heritage regeneration.

Figure 4.4 Fiat Lingotto Factory Before and After Renovation

Source: Drawn by the author based on official documents.

4.3 Overall Characteristics of Turin’s Industrial Heritage Transformation

The transformation of Turin’s industrial heritage has undergone a significant evolution, shifting from a single-purpose manufacturing function to a diverse and multifunctional urban fabric. Driven by urban renewal initiatives, the value of industrial heritage has been redefined, extending beyond mere historical preservation to embrace innovative spatial adaptations that integrate cultural, economic, social, and ecological dimensions. This section, based on an analysis of exemplary industrial heritage transformation cases in Turin, summarizes its overall characteristics, explores the diverse transformation models adopted, examines the synergy between heritage conservation and urban regeneration, and identifies the limitations and challenges currently faced in this process.

4.3.1 Diversification of Transformation Models

The analysis of the three exemplary cases in the previous section highlights the diverse and insightful transformation models that have emerged in the redevelopment of Turin's industrial heritage.

The first is the brownfield ecological regeneration model (Parco Dora), which involves transforming large-scale, contiguous abandoned industrial sites into urban green spaces and public areas. This model is primarily driven by environmental remediation and landscape design, emphasizing the integration of preserved industrial relics into ecological landscapes to create unique public open spaces. Its innovation lies in achieving a synergy between ecological restoration, social benefits, and aesthetic values. The key takeaway from this model is that for heavily polluted industrial sites where buildings cannot be preserved, repurposing them as parkland provides an effective way to allow the city to "breathe." At the same time, retaining symbolic industrial structures helps sustain historical memory.

The second is the cultural and innovation industry integration model (OGR), which repurposes abandoned industrial buildings into cultural and innovation-driven spaces, forming new functional hubs in the city. This model is typically led by governments or public institutions, attracting visitors through the introduction of artistic, exhibition, and performance functions, followed by the integration of business incubators and technology research facilities to stimulate economic activity. The OGR experience demonstrates that a “culture-first, industry-following” approach effectively injects long-term development momentum into large-scale industrial heritage sites. The key to success in this model lies in multi-stakeholder investment and operational collaboration, ensuring that cultural and industrial functions are spatially integrated in a mutually reinforcing manner.

The third is the mixed-use complex redevelopment model (Lingotto), which applies a comprehensive development approach to large-scale industrial buildings by incorporating commercial, office, hotel, and educational functions into a single integrated space. This model emphasizes high-quality architectural design to enable multiple functions to coexist within a heritage structure. The strategy prioritizes preserving the exterior architectural features while innovatively reorganizing the interior spaces to meet contemporary needs. The success of Lingotto demonstrates that large-scale industrial plants can be transformed into new urban landmarks, provided there is a clear functional vision and a strong development entity overseeing the process.

At a broader level, Turin’s industrial heritage transformation follows a corridor-based, networked strategy guided by urban planning. The Spina Centrale master plan connects multiple industrial heritage projects, forming a continuous urban regeneration corridor. This demonstrates a shift from isolated redevelopment efforts to a more integrated renewal approach, where infrastructure improvements and public space development amplify the overall impact. For instance, the underground rail conversion, the creation of tree-lined boulevards, parks, and transit hubs have linked Lingotto, OGR, and Parco Dora, facilitating movement and resource sharing within the corridor. This model underscores the importance of situating industrial heritage redevelopment within the broader urban spatial network, leveraging systematic planning to enhance synergy among projects, creating a “1+1>2” effect.

In conclusion, Turin’s experience demonstrates that industrial heritage transformation is not a one-size-fits-all process; instead, models should be adapted to local conditions. However, regardless of the model, the core principle is to innovatively balance preservation and development—safeguarding industrial cultural heritage while injecting contemporary functions and vitality. The successes of Parco Dora, OGR, and Lingotto illustrate that effective projects identify the intersection between heritage and future needs—whether through green ecology, cultural creativity, or urban mixed-use redevelopment—ultimately achieving a win-win between historical value and contemporary utility. These cases provide valuable insights for other post-industrial cities, demonstrating that through diverse transformation pathways, industrial heritage can be an asset for urban renewal rather than a liability.

4.3.2 The Synergistic Relationship Between Industrial Heritage Conservation and Urban Renewal

Turin’s industrial heritage transformation is not solely focused on the renovation of buildings and spaces; rather, it is deeply embedded within a broader urban development strategy, forming a multidimensional model that integrates spatial, economic, social, and cultural elements in a coordinated manner. This process extends beyond physical spatial restructuring, encompassing industrial restructuring, urban function optimization, and social identity reconstruction.

First, the optimization of spatial structure and the enhancement of functional adaptability are fundamental pillars of Turin’s industrial heritage reuse. Through the implementation of the Spina Centrale plan, the spatial layout of industrial heritage sites was restructured, and previously fragmented infrastructure and abandoned factory districts were incorporated into the city's overall planning framework. As a result, industrial heritage sites ceased to be isolated historical fragments and instead became integral components of the urban spatial system. For instance, the underground railway conversion project not only eliminated the physical division previously imposed on the city but also created new opportunities for the redevelopment of former industrial areas along the railway corridor. Additionally, the surrounding public spaces of industrial heritage sites were enhanced, with the construction of tree-lined boulevards, pedestrian pathways, and green landscapes, improving the city's overall accessibility and enabling these historical buildings to integrate more seamlessly into the urban living network.

Second, economic and industrial upgrading progressed alongside urban revitalization. The reuse of industrial heritage is not merely about architectural preservation; it also serves as a key driver of economic transformation. Turin's transformation strategy illustrates that industrial heritage can act as a vital platform for cultural and creative industries, technological innovation, and tourism economies. For example, the repurposing of the OGR railway workshop not only introduced art exhibitions and performing arts but also attracted technology incubators and innovation labs, forming a unique "culture + technology" integrated development model. This approach successfully facilitated the clustering of creative industries, transforming traditional industrial zones into catalysts for urban vibrancy. Meanwhile, the Lingotto factory's redevelopment adopted a comprehensive development strategy, integrating commercial, office, educational, and exhibition functions, maximizing economic benefits while preserving historical value. These cases demonstrate that, through carefully designed functional repurposing and industrial integration, industrial heritage sites can become powerful engines driving urban economic revitalization.

Additionally, social participation and cultural identity enhancement are defining features of Turin's industrial heritage transformation. Traditionally, the conservation and adaptive reuse of industrial heritage have often been top-down processes led by governments and developers. However, Turin's experience reveals that public engagement played a pivotal role in ensuring the success of these projects. For example, during the transformation of Parco Dora, the local government actively involved residents in discussions about design proposals and later established community-based management mechanisms for ongoing operations. As a result, the park not only became a symbol of ecological restoration but also a representation of community cultural identity. This successful model underscores the fact that industrial heritage reuse is not just about spatial and economic restructuring; it also involves rebuilding social connections. Only with strong community support and cultural recognition can industrial heritage conservation and transformation achieve long-term sustainability.

In conclusion, Turin's industrial heritage transformation is a multidimensional, coordinated process, encompassing spatial restructuring, industrial upgrading, economic transition, and cultural identity reinforcement. This model has not only enhanced the city's overall competitiveness but has also provided valuable insights for other industrial cities around the world facing similar challenges.

4.3.3 Limitations and Challenges of Turin's Industrial Heritage Transformation

Despite the significant achievements in Turin's industrial heritage transformation, several challenges persist throughout the process. These challenges extend beyond policy coordination, economic feasibility, social acceptance, and environmental governance, encompassing broader issues such as governance mechanisms, financial stability, functional adaptability of industrial heritage, and sustainable long-term operational models.

First, the instability of policy sustainability and coordination mechanisms poses a major obstacle. While the Spina Centrale plan provided a macro-level framework for urban renewal, inconsistencies in policy implementation have slowed down progress in specific projects. The complexity of interdepartmental coordination often results in delays or long-term project stagnation. Furthermore, industrial heritage reuse involves multiple stakeholders, including municipal authorities, developers, cultural institutions, local communities, and environmental organizations, whose conflicting interests frequently lead to policy execution disputes.

Second, long-term economic feasibility and challenges in securing funding remain significant hurdles. Industrial heritage redevelopment typically requires substantial financial investment, yet the long payback period discourages private investors who seek short-term returns. For example, the OGR railway workshop transformation project, though ultimately successful, heavily relied on government subsidies, public-private partnerships, and guided investment funds in its early stages. The replicability of this model in other industrial heritage projects remains uncertain. In addition, some sites with poor locations or deteriorating structures have low commercial value, making it difficult to attract investors, resulting in long-term underutilization. Moreover, complex property rights structures create barriers to investment, as unclear ownership or disputes over land use rights discourage potential stakeholders from committing to long-term redevelopment plans.

Third, the complexity of social acceptance and cultural identity presents challenges. Industrial heritage transformation is not merely about physical space reuse; it also involves the preservation and transmission of urban historical memory. However, perceptions of industrial heritage value differ across social groups. For instance, some local residents prioritize historical preservation to maintain cultural significance, whereas developers focus on maximizing land value through commercial redevelopment. This conflict emerged in several cases, such as the Lingotto factory transformation, where architectural conservationists and commercial developers debated the extent to which the site’s original functions should be preserved or repurposed. Striking a balance between preserving industrial heritage and adapting it to modern urban needs remains a crucial challenge. Given that many industrial sites have lost their original production functions, identifying new urban roles that align with contemporary societal demands while maintaining coherence with the site's historical attributes is an ongoing concern for planners and policymakers.

Fourth, environmental governance and sustainability pressures present another set of challenges. Many former industrial sites suffer from severe environmental contamination, particularly due to inadequate pollution control measures in the past. Issues such as soil, groundwater, and air pollution pose significant remediation costs and complicate redevelopment efforts. For example, prior to its redevelopment, the Dora River industrial zone faced serious heavy metal contamination, necessitating long-term environmental restoration efforts, which significantly increased project costs. Additionally, industrial heritage conversion often involves the disposal of large volumes of construction materials, raising concerns about carbon emissions and sustainable resource management. While Turin successfully integrated ecological restoration with landscape design in the Dora Park project, the feasibility of replicating this model in other highly polluted industrial sites remains uncertain due to challenges related to policy support, funding, and technological requirements.

Fifth, functional adaptability and long-term operational models for industrial heritage reuse require further attention. Industrial heritage transformation is not just a one-time redevelopment project; it demands continuous functional adjustments and sustainable operational frameworks. For instance, the success of OGR was not only due to its spatial repurposing but also to the integration of diverse industries, including culture, technology, and commerce. However, many industrial heritage projects continue to struggle with functional misalignment after redevelopment. Some sites, converted into commercial complexes or office spaces, fail to attract tenants due to a lack of supporting infrastructure and economic integration, ultimately compromising their long-term viability. Therefore, ensuring that industrial heritage revitalization aligns with evolving urban development trends, while establishing flexible operational models that sustain long-term vitality, remains a crucial task for future urban planners.

In conclusion, while Turin's industrial heritage transformation has demonstrated significant successes, it also highlights multiple unresolved challenges. Addressing policy consistency, economic feasibility, social engagement, environmental sustainability, and operational resilience will be essential for ensuring the long-term success and scalability of industrial heritage redevelopment efforts.

5 Collaborative Assessment System for Industrial Heritage Transformation Based on Social Network Analysis

5.1 Constructing a Collaborative Evaluation Framework Using Social Network Analysis

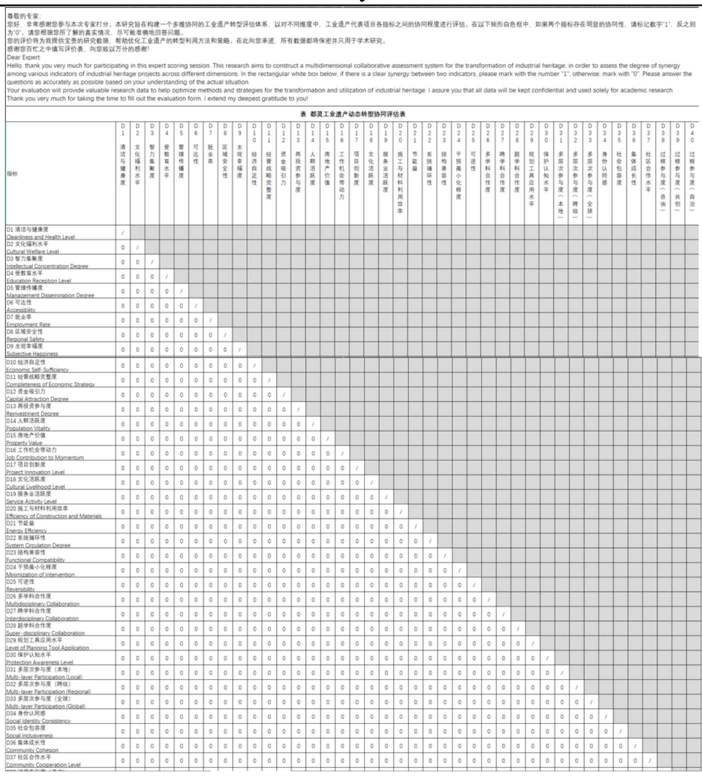
The transformation of industrial heritage involves multiple objectives and factors, including economic, social, cultural, and environmental aspects, with its complexity reflected in the interactive relationships and synergies among various dimensions. Traditional single-dimensional or linear evaluation methods fail to fully capture the mechanisms influencing industrial heritage transformation. Therefore, this study, from the perspective of synergetics, constructs a multi-dimensional collaborative evaluation system for industrial heritage transformation and integrates Social Network Analysis (SNA) to quantitatively analyze the synergies between evaluation elements, providing a scientific basis for optimizing transformation strategies.

As discussed in Chapter 3, the construction of the evaluation system is based on a systematic review of international industrial heritage conservation and transformation assessment frameworks, combined with localized practical experience in Italy. This study selects key dimensions and indicators to measure the quality of industrial heritage transformation, drawing on frameworks such as the ICOMOS principles for industrial heritage protection, the values of the New European Bauhaus (NEB), and Italy's National Index of Fair and Sustainable Well-being (BES). Based on these references, an indicator system was developed that includes four core dimensions: social well-being, economic development, environmental sustainability, and cultural and social governance. The research team then invited experts from relevant fields to refine the indicator system using the Delphi method, ultimately establishing a hierarchical evaluation framework structured according to dimensions, domains, criteria, and elements.

The structure of this evaluation system is as follows: at the first level is the overall goal, which is the quality of industrial heritage transformation. At the second level, four primary dimensions are defined: social well-being, economic development, environmental sustainability, and cultural and social governance. The third level consists of secondary indicators, further breaking down the core dimensions into key evaluation areas. The fourth level includes tertiary indicators, which refine the evaluation elements to support quantitative analysis. For example, within the social well-being dimension, five key domains are identified: health, knowledge and education, work-life balance, safety, and subjective well-being. These domains are further broken down into seven criteria, including physical health, mental health, intelligence, knowledge, employment opportunities, safety, and subjective well-being. Ultimately, nine specific elements are established, such as cleanliness and health conditions, cultural well-being, intellectual concentration, education levels, management and communication, accessibility, employment rates, regional safety, and subjective happiness. This hierarchical framework ensures the comprehensiveness and systematic nature of the evaluation model and lays the foundation for subsequent synergy analysis.

To reveal the interrelationships among evaluation elements in the process of industrial heritage transformation, this study introduces Social Network Analysis (SNA) to depict the structural interactions between evaluation indicators and quantify the degree of synergy. Originally developed in sociology, SNA has been widely applied in organizational management, policy communication, and technological collaboration. The core idea is to regard each evaluation element as a node and the synergistic relationships between elements as edges, using network structure analysis to identify key collaborative elements and their influence mechanisms.

In applying Social Network Analysis, the first step is to establish a data foundation for the synergy network. To determine the relationships among different evaluation elements in industrial heritage transformation, experts in the field were invited to assess case studies and provide ratings on whether two elements exhibit significant synergy in transformation projects. Specifically, experts evaluated whether a positive correlation exists between two elements and assigned a synergy score based on their strength of association. If most experts agreed that a strong positive correlation exists between two elements, they were considered to be linked, recorded as synergy = 1; if no significant correlation was observed, no link was recorded, meaning synergy = 0.



尊敬的专家：
您好，非常感谢您参与本次专家打分。本研究旨在构建一个多维协同的工业遗产转型评估体系，以对不同维度中，工业遗产代表项目各指标之间的协同程度进行评估。在以下矩形白色框中，如果两个指标存在明显的协同性，请标记数字"1"，反之则为"0"。请您根据您所了解的真实情况，尽可能准确地回答问题。
您的评价将为我提供宝贵的研究数据，帮助优化工业遗产的转型利用方法和策略。在此向您承诺，所有数据都将保密并只用于学术研究。
感谢您百忙之中填写评价表，向您致以万分的感谢!
Dear Expert:
Hello, thank you very much for participating in this expert scoring session. This research aims to construct a multidimensional collaborative assessment system for the transformation of industrial heritage, in order to assess the degree of synergy among various indicators of industrial heritage projects across different dimensions. In the rectangular white box below, if there is a clear synergy between two indicators, please mark with the number "1"; otherwise, mark with "0". Please answer the questions as accurately as possible based on your understanding of the actual situation.
Your evaluation will provide valuable research data to help optimize methods and strategies for the transformation and utilization of industrial heritage. I assure you that all data will be kept confidential and used solely for academic research.
Thank you very much for taking the time to fill out the evaluation form. I extend my deepest gratitude to you!

表 都灵工业遗产动态转型协同评估表

指标	D1 清洁与健康度	D2 文化福利水平	D3 智力集聚度	D4 受教育水平	D5 管理传播度	D6 可达性	D7 就业率	D8 区域安全性	D9 主观幸福度	D10 经济自足性	D11 经营战略完整度	D12 资金吸引力	D13 再投资参与度	D14 人群活跃度	D15 房地产价值	D16 工作机会带动力	D17 项目创新度	D18 文化活跃度	D19 服务业活跃度	D20 施工与材料利用效率	D21 节能量	D22 系统循环性	D23 结构兼容性	D24 干预最小化程度	D25 可逆性	D26 多学科合作度	D27 跨学科合作度	D28 超学科合作度	D29 规划工具应用水平	D30 保护认知水平	D31 多层次参与度（本地）	D32 多层次参与度（跨级）	D33 多层次参与度（全球）	D34 身份认同感	D35 社会包容度	D36 集体成长性	D37 社区合作水平	D38 过程参与度（咨询）	D39 过程参与度（共创）	D40 过程参与度（自治）
D1 清洁与健康度 Cleanliness and Health Level	/																																							
D2 文化福利水平 Cultural Welfare Level	0	/																																						
D3 智力集聚度 Intellectual Concentration Degree	0	0	/																																					
D4 受教育水平 Education Reception Level	0	0	0	/																																				
D5 管理传播度 Management Dissemination Degree	0	0	0	0	/																																			
D6 可达性 Accessibility	0	0	0	0	0	/																																		
D7 就业率 Employment Rate	0	0	0	0	0	0	/																																	
D8 区域安全性 Regional Safety	0	0	0	0	0	0	0	/																																
D9 主观幸福度 Subjective Happiness	0	0	0	0	0	0	0	0	/																															
D10 经济自足性 Economic Self-Sufficiency	0	0	0	0	0	0	0	0	0	/																														
D11 经营战略完整度 Completeness of Economic Strategy	0	0	0	0	0	0	0	0	0	0	/																													
D12 资金吸引力 Capital Attraction Degree	0	0	0	0	0	0	0	0	0	0	0	/																												
D13 再投资参与度 Reinvestment Degree	0	0	0	0	0	0	0	0	0	0	0	0	/																											
D14 人群活跃度 Population Vitality	0	0	0	0	0	0	0	0	0	0	0	0	0	/																										
D15 房地产价值 Property Value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																									
D16 工作机会带动力 Job Contribution to Momentum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																								
D17 项目创新度 Project Innovation Level	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																							
D18 文化活跃度 Cultural Livelihood Level	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																						
D19 服务业活跃度 Service Activity Level	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																					
D20 施工与材料利用效率 Efficiency of Construction and Materials	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																				
D21 节能量 Energy Efficiency	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																			
D22 系统循环性 System Circulation Degree	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																		
D23 结构兼容性 Functional Compatibility	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																	
D24 干预最小化程度 Minimization of Intervention	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																
D25 可逆性 Reversibility	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/															
D26 多学科合作度 Multidisciplinary Collaboration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/														
D27 跨学科合作度 Interdisciplinary Collaboration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/													
D28 超学科合作度 Super-disciplinary Collaboration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/												
D29 规划工具应用水平 Level of Planning Tool Application	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/											
D30 保护认知水平 Protection Awareness Level	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/										
D31 多层次参与度（本地） Multi-layer Participation (Local)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/									
D32 多层次参与度（跨级） Multi-layer Participation (Regional)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/								
D33 多层次参与度（全球） Multi-layer Participation (Global)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/							
D34 身份认同感 Social Identity Consistency	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/						
D35 社会包容度 Social Inclusiveness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/					
D36 集体成长性 Community Cohesion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/				
D37 社区合作水平 Community Cooperation Level	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/			

Figure 5.1 Example of Binary Scale Design for Expert Scoring

Source: Drawn by the author.

During the data processing phase, a symmetric adjacency matrix was constructed based on expert evaluation results to establish the synergy network. The rows and columns of the matrix represent different evaluation elements, while the values within the matrix indicate the synergy relationships between them. To enhance the scientific rigor and reliability of the data, this study applied weighted processing to the evaluation results. Only when the mean synergy score of a pair of elements exceeded a predefined threshold (such as the overall mean score or the top 75th percentile) was the relationship considered valid. This filtering process effectively reduces random errors and highlights the most significant synergies, providing precise data support for subsequent network analysis.

Once the data processing was completed, the synergy network matrix was imported into the specialized SNA software UCINET for network visualization. By converting the data into a topological network graph, the synergistic relationships between industrial heritage transformation elements were intuitively displayed. In the generated network graph, each evaluation element was represented as a "node," while the synergy relationships between elements were depicted as "edges" or links. Additionally, the strength of the links (weights) indicated the intensity of synergy, making strongly interconnected elements more prominent and thus revealing the structural characteristics within the system more clearly.

During the network structure analysis phase, this study calculated several key network indicators to examine the internal characteristics and mechanisms of the synergy network. First, network density was computed to measure the overall cohesion of the system. A higher network density indicates stronger synergy between evaluation elements, suggesting a higher degree of interaction among different dimensions in the industrial heritage transformation process. Second, centrality analysis was conducted, including degree centrality and betweenness centrality, to identify key elements within the synergy network. Elements with high degree centrality typically have numerous connections within the network, indicating their crucial influence in the transformation process. Meanwhile, elements with high betweenness centrality serve as bridges in the synergy network, playing a pivotal role in facilitating coordination and optimization. Lastly, a core-periphery analysis was performed to examine the distribution of nodes within the network, distinguishing between core and peripheral elements. This analysis helps reveal how different evaluation elements interact dynamically in the transformation process and provides insights for future policy formulation and optimization.

The collaborative evaluation system developed in this study, integrating social network analysis, offers a novel research approach to assessing industrial heritage transformation. First, this study establishes a comprehensive multi-dimensional evaluation framework, addressing the limitations of previous methodologies that often focused solely on historical preservation or economic benefits. The proposed framework encompasses four core dimensions—social well-being, economic development, environmental sustainability, and cultural and social governance—ensuring a holistic assessment of industrial heritage transformation. By considering these dimensions comprehensively, the study provides a more precise understanding of how heritage transformation impacts various social groups, economic structures, ecological environments, and governance systems, thereby enhancing the comprehensiveness and practical applicability of the evaluation system.

Second, by introducing SNA, this study quantitatively analyzes the synergy relationships between different evaluation elements in industrial heritage transformation. Traditional evaluation methods often rely on linear weighting models, making it difficult to capture the complex, nonlinear interactions among elements. SNA, however, enables the conversion of qualitative experience data into structured relational data and, through network analysis tools, reveals the topological characteristics of the synergy network. This approach not only clarifies the interactions between elements but also quantifies synergy intensity and network structure. For example, network density is used to evaluate overall synergy levels, centrality analysis identifies the most influential elements, and subgroup analysis detects potential coupled relationships between elements.

Regarding the identification of key driving factors, this study employs SNA to calculate network centrality, determining which elements play a dominant role in the transformation process. The results provide a quantitative foundation for optimizing transformation strategies. For instance, if "cultural identity" exhibits high centrality in the synergy network, it suggests that community identity plays a crucial role in promoting heritage conservation and social sustainability. Therefore, policymakers should strengthen community engagement mechanisms to enhance public recognition and participation in industrial heritage transformation. Similarly, if "project innovation capacity" demonstrates high centrality, it indicates that fostering cultural and creative industries and emerging sectors within heritage spaces is a key strategy for increasing economic value.

Furthermore, the introduction of SNA provides a scientific foundation for refining industrial heritage transformation policies. By analyzing weakly connected elements in the synergy network, the study identifies gaps in the transformation process and offers targeted policy recommendations. For example, if environmental governance elements are found to be peripheral in the network, it indicates insufficient attention to ecological sustainability in current heritage transformation efforts, potentially leading to long-term environmental issues. In response, governments and relevant institutions should prioritize green technology applications and increase the emphasis on environmental protection in industrial heritage redevelopment to ensure sustainability goals are met. Likewise, if "multi-level participation (cross-sectoral collaboration)" exhibits low connectivity in the network, it suggests that cooperation between government, businesses, and communities remains underdeveloped. This calls for further refinement of cross-departmental governance models to enhance management efficiency in the heritage transformation process.

In summary, the collaborative evaluation system developed in this study, incorporating SNA, provides a scientific and systematic quantitative analysis tool for assessing industrial heritage transformation. This methodology not only precisely identifies key driving factors in the transformation process but also reveals the synergy patterns among different elements, offering policymakers data-driven support for optimizing transformation strategies.

5.2 Collaborative Evaluation Data Collection

This study selected three representative industrial heritage transformation projects in the city of Turin—namely Parco Dora, the OGR Innovation Hub, and the Lingotto Complex (as introduced in Chapter 4)—as evaluation case studies. The rationale for choosing these cases lies in their diverse typologies (a park, a cultural innovation center, and a commercial complex), their proven success, and their exemplary significance as reference models. Additionally, all three projects are part of the broader Spina Centrale (Central Spine) planning framework, ensuring comparability under a unified macro-level objective.

For the evaluation framework, each case was assessed based on its state before and after transformation, analyzing the synergy network of different evaluation elements at both stages. The "pre-transformation" phase refers to the site's condition before redevelopment was initiated—for example, Parco Dora was an abandoned industrial zone, OGR was a decommissioned railway maintenance facility, and Lingotto was a closed-down automobile factory. The "post-transformation" phase refers to the operational state after the site was repurposed and put to new use. By comparing the synergy networks before and after transformation, the study aims to observe the changes brought about by redevelopment.

Data collection was primarily conducted through expert surveys, where multiple specialists, researchers, planners, and project managers were invited to complete a synergy assessment questionnaire. To ensure professional diversity and expertise, the expert panel consisted of scholars in architecture and urban planning (with over five years of research experience), architects involved in the projects, industrial heritage specialists, and historical and cultural experts, totaling 26 participants. Each expert evaluated the relationships between 40 evaluation elements for each case study, assessing their pairwise associations. A total of 156 questionnaires were distributed, with 143 valid responses collected, resulting in a response rate of 91.7%. This yielded a dataset of 111,540 valid evaluation entries. The extensive dataset ensures the reliability and objectivity of the synergy assessment.

Table 5.1 Distribution and Collection of Questionnaires

Round	Participants	Questionnaires Distributed	Questionnaires Collected	Data Volume	Effective Response Rate (%)
1	12	72	67	52,260	93.1%
2	8	48	42	32,760	87.5%
3	6	36	34	26,520	94.4%
Total	26	156	143	111,540	91.7%

Source: Compiled by the author based on expert questionnaire survey results.

During the data analysis phase, the expert judgment results were first aggregated to generate a comprehensive synergy adjacency matrix for both the "pre-transformation" and "post-transformation" states of each case study. Subsequently, key SNA (Social Network Analysis) indicators were calculated for these networks, including network density (which reflects the overall level of synergy) and centrality measures (which identify key elements that play a pivotal role in the transformation process). By comparing the structural evolution of synergy networks before and after redevelopment, this analysis helps reveal the impact of transformation on the interconnections between evaluation elements.

In addition to these core SNA indicators, further statistical tests and correlation analyses were conducted for selected variables. For instance, the study compared the number of synergy relationships across different dimensions to identify variations in collaborative intensity. Furthermore, correlation coefficients were used to examine whether the strength of certain synergies had a significant relationship with project performance indicators. These additional tests allowed for a deeper exploration of the underlying mechanisms driving industrial heritage transformation.

To maintain comparability and consistency, the analysis framework followed a standardized process across all three case studies. This ensured that the evaluation methods and results remained aligned, facilitating meaningful cross-case comparisons. In the interpretation of findings, attention was paid not only to the specific improvements and limitations of each case but also to identifying common patterns and trends across the projects. These shared insights serve as a foundation for refining future transformation strategies, providing evidence-based recommendations for optimizing industrial heritage redevelopment.

5.3 Synergy Evaluation Analysis Indicators

After constructing the synergy evaluation network for industrial heritage transformation, a series of network analysis indicators are required to quantify the structure and characteristics of the synergy relationships. Social Network Analysis (SNA) provides a mature set of quantitative analysis methods that can reveal the degree of synergy between different elements, the role of core elements in the network, and the overall structural patterns of the network. In this study, the case analyses utilize key indicators such as Network Density, Degree, Network Centrality, Core-Periphery Fit, and Key Nodes to depict the synergy patterns and their variations during industrial heritage transformation. Below is a detailed explanation of each indicator and its significance in this research.

（1）Network Density

Network Density measures the ratio of actual connections in the synergy network to the theoretically possible maximum connections, with values ranging between 0 and 1. A network density close to 1 indicates that almost all elements in the network are interconnected, reflecting a high level of synergy. Conversely, a lower density suggests that most elements lack direct synergy. In this study, network density is used to assess the overall level of synergy in industrial heritage transformation. The higher the density, the more tightly the transformation elements interact, resulting in a more efficient synergy relationship. For instance, in successful transformation cases, environmental, social, economic, and cultural factors tend to form a high-density network, demonstrating the advantage of multidimensional synergy.

（2）Degree (Linkage Count)

Degree (also known as Node Degree) refers to the number of direct connections a given element has with other elements in the network. This indicator reflects an element's direct influence within the network. In the context of industrial heritage transformation, elements with high degree values are usually key drivers of transformation, such as cultural identity, environmental quality improvements, and economic vitality. If a particular type of element exhibits high linkages in a case study, it signifies that the element plays a central role in the transformation process, impacting multiple aspects of the project. For example, in ecological restoration projects, environmental quality often has a high degree value, indicating its strong synergistic impact on economic and social development.

（3）Network Centrality

Network Centrality is used to assess how central a particular element is within the entire network. This study employs three commonly used centrality measures: Degree Centrality, Betweenness Centrality, and Closeness Centrality.

Degree Centrality measures the number of direct connections an element has with other elements, further quantifying its degree value. In transformation networks, elements with high degree centrality serve as key synergy nodes.

Betweenness Centrality reflects an element’s "bridging" role in the network, indicating whether the element acts as an intermediary between other elements, facilitating the flow of information and resources. If an element serves as a crucial intermediary between different sub-networks, it plays a key hub role in the synergy network. For example, if "Cultural Activities" exhibit high betweenness centrality between the economic and social networks, it indicates that cultural elements serve as a bridge between industrial revitalization and social cohesion.

Closeness Centrality measures how quickly an element can influence all other elements in the network by calculating its average shortest path distance to other nodes. Elements with high closeness centrality serve as core drivers of transformation because they can rapidly affect other key transformation factors.

（4）Core-Periphery Fit

Core-Periphery Fit measures whether a network exhibits a hierarchical structure with "core elements" and "peripheral elements." In highly synergistic transformation networks, certain key elements occupy a central position, connecting many other elements, while some secondary elements remain on the periphery with fewer connections. This study calculates Core-Periphery Fit to identify which elements serve as core drivers and which ones are secondary components in the transformation process.

For example, in industry-oriented transformation cases, economic factors often occupy the core, while environmental management might be secondary. However, in cultural revitalization cases, cultural identity and social participation could become core elements. Understanding core-periphery dynamics allows policymakers and urban planners to focus on strengthening core elements while strategically integrating peripheral elements into the transformation process.

（5）Key Nodes

Key Nodes refer to the most influential elements within the entire network structure. These are usually identified based on the highest Degree Centrality or Betweenness Centrality. In this study, identifying key nodes helps to understand which elements dominate different types of industrial heritage transformation projects. For example: In innovation-driven transformation projects, key nodes might include "Knowledge Innovation" and "Startup Incubation". In ecological restoration projects, "Environmental Quality" and "Green Infrastructure" could emerge as key nodes. In socially driven projects, key nodes may include "Community Identity" and "Public Participation".

Recognizing key nodes helps guide future transformation strategies. If a project's success depends heavily on "Community Identity," it indicates that strong community engagement and cultural activities are essential for sustainable transformation. Similarly, if "Project Innovation" has a strong centrality, fostering cultural and technological innovation within industrial heritage spaces could be a critical economic revitalization strategy.

5.4 Analysis of Synergy Evaluation Results in Case Studies

5.4.1 Dora River Industrial Area Transformation Synergy Assessment

（1）Network Structure and Synergy Degree Changes

Before transformation, the synergy network centrality of the Dora River Industrial Area was 0.1619, exhibiting a low-density, highly fragmented structure. The pre-transformation network density was 0.186, while the core-periphery fit score was 0.3716, indicating that the various evaluation factors lacked an organic connection.

Due to prolonged abandonment, the area suffered from environmental degradation, low land-use efficiency, and poor social security, preventing environmental, economic, and social factors from forming an effective synergy effect. For example, "Environmental Sustainability" and "Culture & Social Governance" exhibited a dual weakness phenomenon, where neither element could reinforce the other. Similarly, economic development indicators, such as "Employment" and "Land Value," were almost negligible and lacked connections with other dimensions, contributing to the overall high level of isolation within the network.

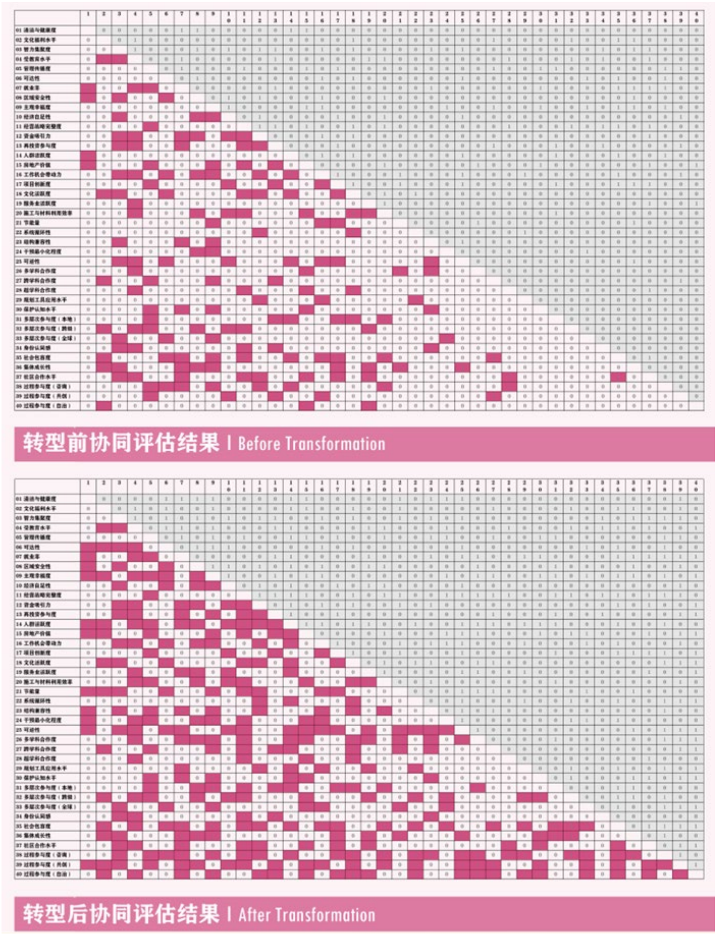


Figure 5.2 Binary Scale for Synergistic Evaluation Before and After the Transformation of the Dora River Industrial Area

Source: Compiled by the author based on questionnaire results.

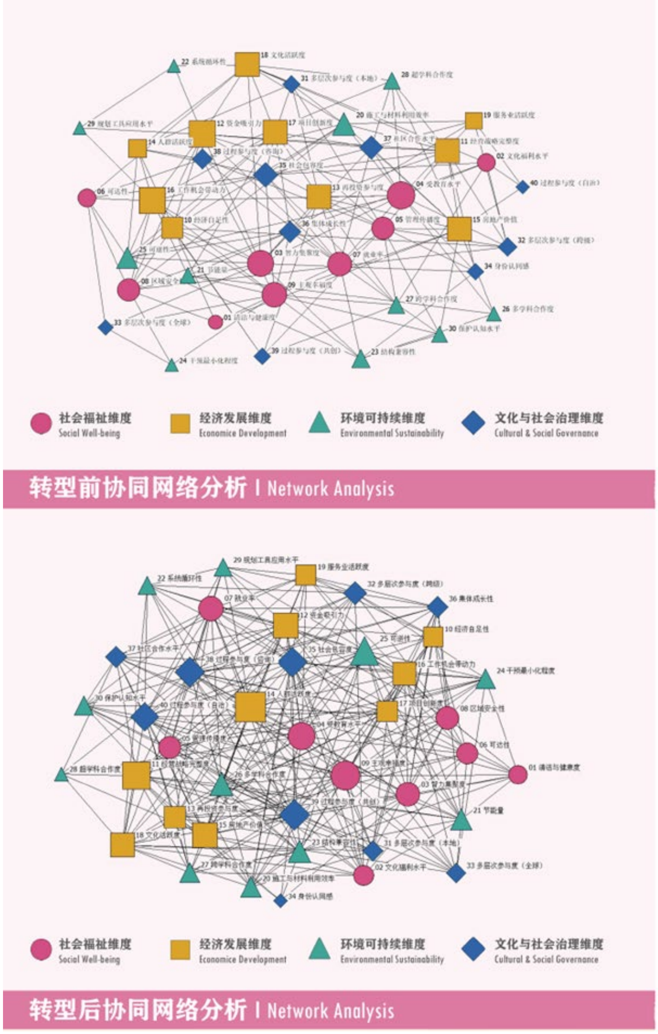


Figure 5.3 Comparison of the Collaborative Networks Before and After the Transformation of the Dora River Industrial Area

Source: Drawn by the author.

After the transformation, the synergy network density of Dora Park significantly increased to 0.369, while the core-periphery fit score rose to 0.3768, indicating that the overall synergy effect of the network was strengthened. Specifically, the number of connections in the network increased from 290 to 576, demonstrating a clear increase in network density. The connections between core elements became tighter, and the network structure became more balanced, with a lower degree of imbalance.

A particularly notable change was the formation of a strong synergy between environmental improvement and social well-being. The successful implementation of greening initiatives and pollution control measures not only enhanced air quality and water purification but also improved residents' health and sense of security. Additionally, the introduction of new public activity spaces facilitated greater neighborhood interaction, reinforcing community identity. These social and environmental factors established a positive feedback mechanism, further driving the network structure toward greater cohesion.

Moreover, the synergy degree of the "Culture & Social Governance" dimension saw a significant improvement after the transformation, indicating that the planning of Dora Park successfully fostered multi-stakeholder engagement. This enabled urban residents to participate more actively in the management and operation of the park, contributing to its long-term sustainability.

Table 5.2 Comparative Network Structure Indicators Before and After the Transformation of the Dora River Industrial Area

Indicator	Before Transformation: Vitali Steel Plant	After Transformation: Dora Park
Network Density	0.186	0.369
Number of Links	290	576
Network Centrality	0.1619	0.2119
Core-Periphery Fit	0.3716	0.3768

Source: Drawn by the author.

（2）Evolutionary Trends of Core Elements

Through core-periphery structure analysis, we can further reveal the role changes of different elements before and after transformation. Before the transformation, the core nodes were primarily concentrated in investment participation, project innovation, construction and material efficiency, collective growth capacity, and community cooperation levels. These elements constituted the major influencing factors during the steel plant's operational phase. However, after the transformation into an urban park, the weight of these elements decreased, gradually shifting toward peripheral factors, while new core elements began to emerge.

After the transformation, accessibility, public engagement, interdisciplinary cooperation, and participatory processes (consultation, co-creation, and self-governance) gradually became the new core elements, forming a new collaborative network center.

This shift reflects how, during the transition of industrial heritage from a production-oriented space to a public cultural and ecological space, social interaction and spatial accessibility gained increasing significance. In Dora Park’s operations, accessibility directly affects its openness and usage efficiency, while increased public engagement promotes the formation of community culture, further reinforcing the social value of heritage transformation. Additionally, the increase in interdisciplinary cooperation suggests that during heritage transformation, the collaborative roles of government, academic institutions, architects, and ecologists were strengthened, making the transformation strategy more systematic and scientifically informed.

（3）Strengthening of Cultural and Social Governance Dimensions

Although Dora Park’s transformation maintained a high synergy between social well-being and economic development, the impact of the cultural and social governance dimension significantly increased after transformation. Comparing network centrality before and after the transformation, the network connectivity of cultural vibrancy, multi-stakeholder participation, and community identity showed substantial growth. For example, community cooperation levels, which were previously peripheral elements, became core elements, indicating that urban residents now play a more significant role in the park's management and operations.

Meanwhile, social network analysis revealed an enhanced synergy within the cultural governance dimension. Particularly under the city’s urban renewal policies, Dora Park has become a key venue for cultural activities in Turin. By hosting music festivals, art exhibitions, and outdoor sports events, the cultural functions of industrial heritage have been reinforced, further strengthening social identity and cohesion.

Notably, although the overall network synergy significantly increased, the synergistic impact of environmental sustainability showed relatively minor changes. This may be related to the priorities of the park’s construction phase. While ecological restoration was a key component of the project, its influence within the synergy network has not yet reached the same level as the social and economic dimensions. Therefore, future heritage transformation strategies should further integrate ecosystem services to achieve a more balanced multidimensional synergy.

（4）Summary and Insights

Through social network analysis of the Dora Park transformation, it becomes evident that industrial heritage transformation is not merely about spatial function replacement but also about dynamic multi-dimensional synergy adjustment. Before the transformation, the synergy network of the Dora River industrial zone was relatively loose, with a core focus on economic development and industrial operations, while social, cultural, and environmental factors had weak connections. After the transformation, the synergy network density of Dora Park significantly increased, the network structure became tighter, and the core elements shifted from economic production factors to social and cultural factors, forming a more balanced synergy network.

This case demonstrates that in industrial heritage transformation, it is crucial to fully consider the synergistic relationships between various elements. Especially in the early stages of planning, establishing a multi-stakeholder participation mechanism can enhance synergy in cultural governance. At the same time, achieving a higher level of coordination between ecological sustainability, economic benefits, and socio-cultural values remains a key challenge for the future adaptive reuse of industrial heritage.

5.4.2 OGR Railway Repair Workshop Transformation Synergy Assessment

（1）Changes in Network Density and Collaborative Structure

Before the transformation, the collaborative network of the OGR repair workshop was relatively loose, with a network density of 0.294 and a core-periphery fit of 0.4527. This indicates that the site had a single-function system with weak synergies. Network graph analysis reveals that industrial production-related elements, such as equipment maintenance, worker employment, and material efficiency, occupied the core of the network, while social, economic, and cultural elements had limited connections, forming a highly enclosed industry-specific synergy structure.

During this phase, OGR primarily functioned as a railway maintenance hub, with minimal interdisciplinary synergy. Its economic impact remained largely confined within the railway industry, failing to establish strong links with urban economic and social development. As a result, the economic nodes within the network were relatively isolated, demonstrating a lack of integration with broader urban functions.

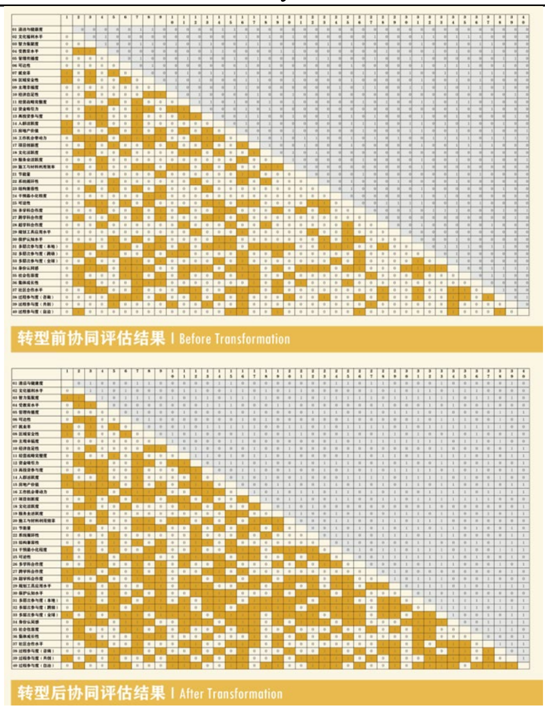


Figure 5.4 Binary Scale for Synergistic Evaluation Before and After the Transformation of OGR

Source: Drawn by the author. based on questionnaire results

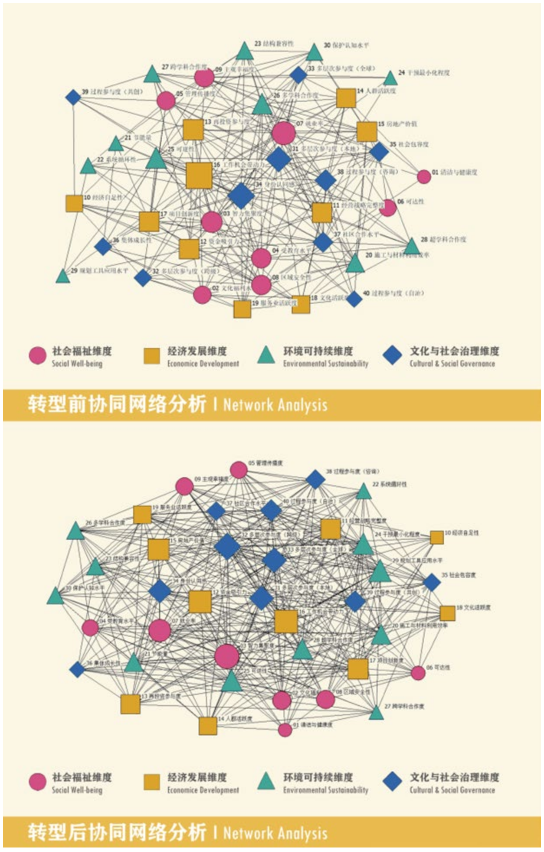


Figure 5.5 Comparative Collaborative Networks Before and After the Transformation of OGR

Source: Drawn by the author.

After the transformation, the synergy network density of OGR significantly increased to 0.487, with the total number of connections in the network rising from 458 to 760. The core-periphery fit also changed to 0.463, indicating that the organizational structure of the synergy network became more compact, and its overall balance improved.

Functionally, OGR evolved from a traditional industrial production space into a hub for technological innovation and cultural creativity, integrating startup incubators and art exhibitions. This new functional framework strengthened the synergy across multiple dimensions, including social well-being, economic development, and cultural governance.

In the post-transformation network visualization, the relationships among synergy elements became more complex, with cross-sector collaborations emerging between different dimensions. For example, the level of social participation became more closely linked to economic investment attractiveness, while the density of cultural activities showed a strong synergy with the innovation and entrepreneurship environment. This transformation demonstrates that OGR's adaptive reuse was not merely a spatial reconfiguration but the establishment of an open and inclusive innovation ecosystem, allowing industrial heritage to play a more significant role in urban development.

Additionally, the synergy between social governance and economic factors was significantly enhanced. The project was managed through a collaborative model between foundations and government authorities, introducing a "multi-level governance" structure as a new core node within the network. This governance model ensured a harmonious balance between cultural programming and commercial operations, facilitating sustainable development while maintaining the site's historical and cultural integrity.

Table 5.3 Comparative Network Structure Indicators Before and After the Transformation of OGR

Indicator	**Before Transformation: Railway Vehicle Maintenance Workshop**	**After Transformation: Startup Incubation Center**
Network Density	0.294	0.487
Number of Links	458	760
Network Centrality	0.3725	0.305

Indicator	Before Transformation: Railway Vehicle Maintenance Workshop	After Transformation: Startup Incubation Center
Core-Periphery Fit	0.4527	0.463

Source: Drawn by the author.

（2）Transformation of Core Elements and Functional Restructuring

Before its transformation, the core elements of the OGR railway workshop primarily revolved around equipment management, worker employment rate, construction material utilization rate, and reinvestment participation—factors that constituted the backbone of the industrial maintenance system. However, as the transition progressed, these traditional industrial economic indicators were gradually marginalized, with some key metrics losing their influence. Instead, a new synergy system emerged, centered on cultural creativity, economic incubation, and social interaction.

In the reconfigured synergy network of the transformed OGR, key driving factors included capital attraction, minimal intervention approach, transdisciplinary collaboration, planning tool application, and multi-level participation. This shift indicates that OGR’s transformation extended beyond physical space renewal, fundamentally restructuring economic, social, and cultural governance dimensions. These changes strengthened cross-sector collaboration among stakeholders, giving OGR a broader socio-economic impact.

A particularly noteworthy change was the rise of cultural governance and social identity as dominant core elements post-transformation. For instance, the cultural vibrancy index, which was only 0.282 before transformation, increased to 0.462 afterward, demonstrating that OGR evolved from an industrial production site into a major cultural activity hub for the city. Additionally, the influence of factors such as multi-stakeholder engagement and participatory governance (co-creation and autonomy) significantly increased, highlighting how OGR's operational model became more inclusive and participatory. The public’s role in site management and event planning expanded, creating a new collaborative governance model. This trend aligns with the European movement toward shared cities and culture-driven urban innovation, positioning OGR as a key platform for social innovation and economic development in Turin.

（3）Enhanced Synergy Between Economic Development and Environmental Sustainability

Throughout OGR's transformation, the synergy within the economic development dimension significantly improved. Prior to its redevelopment, OGR's economic impact was largely confined to the railway industry, with core indicators such as equipment maintenance efficiency and supply chain stability demonstrating weak linkages to the broader urban economy. However, post-transformation, capital attraction, startup incubation, and industrial upgrading emerged as new economic core factors. While the centrality of economic indicators slightly decreased from 0.3725 to 0.305, the overall connectivity and cross-sector synergy within the network expanded dramatically. This shift suggests that OGR's new economic model became more diverse, no longer relying on a single industrial chain but instead establishing an open economic ecosystem that attracted external investment and innovation resources, driving Turin's innovation economy.

In terms of environmental sustainability, although OGR's redevelopment was not primarily focused on ecological restoration, related sustainability indicators still improved within the synergy network. For example, energy efficiency and renewable resource utilization demonstrated stronger collaborative effects post-transformation, indicating that environmental sustainability considerations played an increasing role within OGR's new functional system. However, compared to the synergy growth seen in cultural governance and economic development, the improvement in environmental sustainability synergy remained relatively modest. This suggests that while OGR's transformation emphasized industrial upgrading and social innovation, ecological sustainability still requires further optimization.

（4）Conclusions and Insights

A comparative analysis of OGR's synergy network before and after transformation reveals that the project was not just a physical space renewal, but a comprehensive restructuring of economic models, social interactions, and cultural governance systems. Prior to its redevelopment, OGR's synergy network revolved around railway maintenance, exhibiting a single-function, low-synergy structure. However, after transformation, OGR's network density significantly increased, and its core elements shifted from industrial production indicators to capital attraction, startup ecosystems, cultural identity, and social participation. This balanced synergy structure facilitated OGR's transition into a multifunctional, highly interactive urban innovation hub.

This case study highlights a crucial takeaway for industrial heritage transformation:

the success of adaptive reuse depends on establishing cross-sector and multi-stakeholder collaboration mechanisms. OGR’s transformation demonstrates that industrial heritage renewal is not merely about spatial redesign but also about integrating economic, social, and cultural frameworks to ensure long-term sustainability. Moreover, future industrial heritage transformations must place greater emphasis on environmental sustainability and social inclusivity, ensuring that heritage sites maximize their social impact while adapting to contemporary urban demands.

5.4.3 Lingotto Factory Transformation Synergy Assessment

（1）Network Density and Synergy Structure Changes

Before the transformation of the Fiat Lingotto factory, its synergy network density was relatively low, recorded at 0.197, with a core-periphery fit of 0.5472. This indicates that under its original production-oriented function, the factory’s synergy relationships were relatively singular, primarily focused on production efficiency, logistics operations, equipment maintenance, and energy utilization—all factors directly linked to industrial production.

From the network visualization, the connections between social well-being and cultural governance were weak, revealing that the Lingotto factory, under its former manufacturing-based operational model, lacked a strong public and social dimension. Its limited integration into the urban economy and social fabric meant that its interaction with the broader city system was minimal, reducing its role beyond industrial functions. Consequently, prior to its redevelopment, Lingotto was largely an isolated production hub rather than an active urban node.

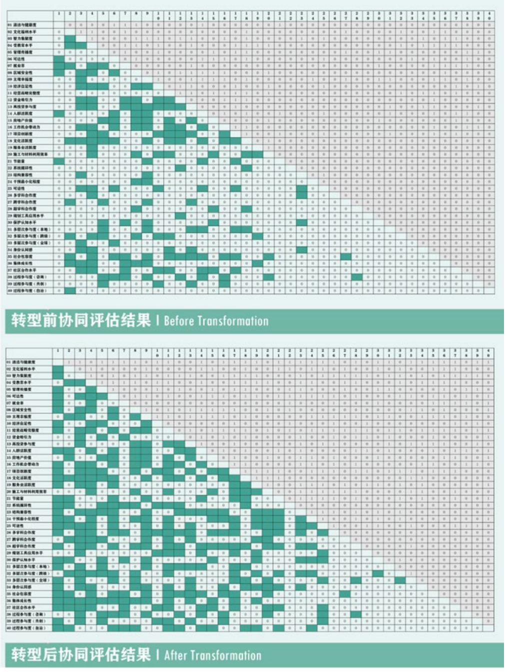


Figure 5.6 Binary Scale for Synergistic Evaluation Before and After the Transformation of Lingotto Factory

Source: Drawn by the author. based on questionnaire results

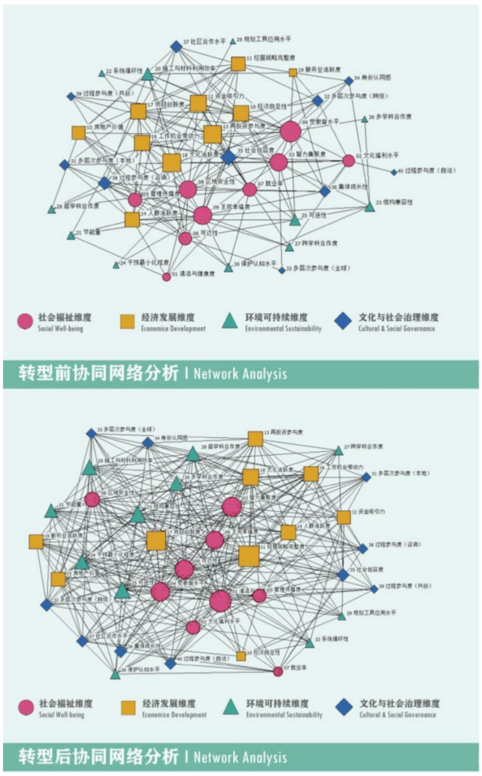


Figure 5.7 Comparative Collaborative Networks Before and After the Transformation of Lingotto Factory

Source: Drawn by the author.

After its transformation, the synergy network density of the Lingotto factory significantly increased to 0.415, with the total number of connections rising from 307 to 647. Meanwhile, the core-periphery fit decreased to 0.4818, indicating that the overall synergy within the network had significantly strengthened, and the network structure became more balanced. The network centrality also increased from 0.2834 to 0.3279, reflecting a trend towards a more centralized synergy network, where certain key factors became the primary driving forces post-renovation.

Following the transformation, the Lingotto complex exhibited broad network coverage with a noticeable economic orientation. Expert evaluations highlighted that economic vitality and employment-related factors emerged as central elements in the new synergy network, forming strong connections with multiple dimensions. For instance, the operation of the commercial and convention center not only created jobs but also boosted Turin's commercial competitiveness, establishing positive synergy with cultural and social factors. Additionally, the integration of university departments into the complex enhanced educational and innovation capabilities, further strengthening the linkage between economic development and the knowledge industry.

Moreover, the synergy of social well-being and environmental sustainability dimensions also improved, signifying that the project had successfully transitioned from a traditional industrial production facility to a multifunctional complex encompassing commerce, services, culture, and technology. This transformation fostered a more advanced and multidimensional synergy network, aligning industrial heritage with contemporary urban development and economic diversification goals.

Table 5.4 Comparative Network Structure Indicators Before and After the Transformation of Lingotto Factory

Indicator	Before Transformation: Fiat Automobile Factory	After Transformation: Commercial Complex
Network Density	0.197	0.415
Number of Links	307	647
Network Centrality	0.2834	0.3279
Core-Periphery Fit	0.5472	0.4818

Source: Drawn by the author.

（2）Changes in Key Elements and Functional Restructuring

Before its transformation, the core elements of the Lingotto factory primarily revolved around production management, equipment maintenance, logistics efficiency, and worker employment, all of which were traditional industrial operational factors. Meanwhile, other dimensions—such as social integration, cultural innovation, and environmental friendliness—had a weaker influence within the synergy network. The core network elements were relatively singular, indicating that, under the automotive manufacturing model, the factory was primarily serving the industrial system and lacked a cross-sectoral synergy mechanism.

After the transformation, the core elements underwent significant changes. New key factors—such as cleanliness and health levels, construction and material utilization efficiency, system circularity, structural compactness, minimal intervention degree, accessibility, interdisciplinary cooperation, and transdisciplinary collaboration—gradually replaced the original industrial production core elements, becoming the new center of the synergy network. This shift demonstrates that the Lingotto factory's redevelopment was not merely a physical spatial transformation but also a deep adjustment in economic models, social interactions, and environmental strategies, allowing it to better align with the needs of modern urban development.

A particularly noteworthy observation is that the cultural governance dimension remained relatively peripheral within the post-transformation synergy network. This suggests that while the transformation of the Lingotto factory enhanced its commercial and social functions, its synergy in cultural identity and historical value transmission remained relatively weak. This may be attributed to the primary objectives of the transformation, which were mainly oriented towards economic revitalization and commercial development rather than pure cultural heritage preservation. As a result, the synergy degree of cultural governance elements still requires further optimization in comparison to other dimensions.

（3）Strengthened Synergy Between Economic Development and Environmental Sustainability

The economic development dimension was significantly reinforced during the Lingotto factory's transformation. Before the transformation, the factory's economic contributions were primarily reflected in the synergy within the automotive manufacturing industry chain. However, post-transformation, its economic functions became more diversified, manifesting in commercial attractiveness, capital investment, job creation, and industrial upgrading, thereby forming a more open economic system. The transformed Lingotto factory not only became a key commercial hub in Turin but also attracted multiple businesses and institutions, further promoting the city's economic diversification.

In terms of environmental sustainability, although the transformation of the Lingotto factory was not primarily focused on ecological restoration, the synergy network revealed an increase in the influence of factors such as energy efficiency, renewable resource utilization, and green building strategies. While the network density of the environmental sustainability dimension did not reach the level of the economic dimension, environmental concerns were still integrated into the transformation process. For example, during the architectural renovation, the Lingotto factory adopted green building technologies, optimized indoor air quality, and introduced energy-saving systems, ensuring that commercial operations could coexist with environmental considerations. However, compared to the economic and social dimensions, synergies related to environmental sustainability still require further strengthening to achieve a more balanced model of sustainable development.

（4）Summary and Insights

The transformation of the Lingotto factory illustrates that industrial heritage reuse is not just about updating physical spaces but also about the systematic restructuring of economic models, social structures, and environmental strategies. Before the transformation, its synergy network was primarily centered around industrial production, with a single-structured and low-synergy framework. However, post-transformation, the synergy network density significantly increased, and key elements expanded beyond production management to include commercial investment, social functionality, and environmental strategies, forming a more complex and multi-dimensional synergy system.

This case highlights that in industrial heritage transformation, establishing cross-sectoral, multi-stakeholder synergy mechanisms is critical to success. The Lingotto factory’s experience demonstrates that the successful reuse of heritage sites requires not only high-quality physical renovations but also the construction of a synergistic framework encompassing economic, social, and environmental dimensions to enhance long-term adaptability. Furthermore, in future industrial heritage renewal projects, greater emphasis should be placed on strengthening the cultural and social governance dimensions, ensuring that heritage transformations not only generate economic benefits but also preserve historical continuity and reinforce social identity.

5.4.4 Comparative Analysis of the Three Cases

This study, based on the social network analysis (SNA) method, conducted a collaborative evaluation of the transformation of three major industrial heritage sites in Turin. It reveals the characteristics of the synergistic evolution of element systems in the process of industrial heritage transformation and their underlying impact mechanisms. By comparing the structural changes in the collaborative network before and after the transformation, as well as the shifts in core elements and the relationships among various dimensions, the following key conclusions can be drawn.

First, in terms of overall synergy, although the overall network density of the industrial heritage collaborative network has increased after transformation, the core-periphery structure remains significant. This indicates that certain core nodes hold strong control and influence within the network, forming a more balanced and dynamically interactive social network structure. Among the three cases, the OGR collaborative network is the most dense and diversified, encompassing comprehensive synergy across economic, cultural, social, and governance dimensions. Lingotto follows, with a strong economic-cultural synergy but a relatively simpler governance network. Dora Park's synergy is primarily concentrated in the environmental-social domain. Specifically, some original core nodes were partially replaced during the transformation, while some peripheral nodes evolved into new core nodes. This characteristic demonstrates that industrial heritage transformation is not merely a one-way structural optimization but rather a multi-element, multi-dimensional collaborative restructuring process.

Table 5.5 Summary of Case Study Data Analysis[①]

Indicator/Element	Lingotto Before Transformation	Lingotto After Transformation	Dora River Industrial Zone Before Transformation	Dora River Industrial Zone After Transformation	OGR Before Transformation	OGR After Transformation
Social Network Analysis Indicators						

① The data marked with an asterisk (*) in the table correspond to core elements in the core-periphery structure, while the rest are peripheral elements.

Indicator/Element	Lingotto Before Transformation	Lingotto After Transformation	Dora River Industrial Zone Before Transformation	Dora River Industrial Zone After Transformation	OGR Before Transformation	OGR After Transformation
Network Density	0.197	0.415	0.186	0.369	0.294	0.487
Number of Ties	307	647	290	576	458	760
Network Centralization	0.2834	0.3279	0.1619	0.2119	0.3725	0.305
Core/Periphery Fit	0.5472	0.4818	0.3716	0.3768	0.4527	0.463
Specific Element Centrality						
01 Cleanliness and Health	0.128	0.744 *	0.103	0.282	0.103	0.282
02 Cultural Welfare	0.231	0.436	0.179	0.333	0.282	0.462
03 Intellectual Aggregation	0.385 *	0.667 *	0.333 *	0.436 *	0.41 *	0.718 *
04 Education Level	0.487 *	0.641 *	0.359 *	0.513 *	0.359	0.385
05 Management Communication	0.282 *	0.436	0.256 *	0.385 *	0.308	0.41
06 Accessibility	0.256 *	0.641 *	0.179	0.359 *	0.231	0.308
07 Employment Rate	0.282 *	0.282	0.282 *	0.462 *	0.513 *	0.641 *
08 Regional Security	0.385 *	0.513 *	0.256 *	0.41 *	0.359 *	0.462
09 Subjective Well-being	0.41 *	0.615 *	0.308 *	0.564 *	0.359 *	0.436
10 Economic Self-Sufficiency	0.333 *	0.256	0.231	0.308	0.205	0.256
11 Strategic Integrity	0.282 *	0.692 *	0.282 *	0.513 *	0.359 *	0.538 *
12 Capital Attractiveness	0.359 *	0.41	0.333 *	0.462 *	0.359	0.641 *
13 Reinvestment Participation	0.385 *	0.462	0.282 *	0.359	0.385 *	0.487
14 Population Engagement	0.308 *	0.487 *	0.179	0.59 *	0.333 *	0.436
15 Real Estate Value	0.256	0.436	0.282 *	0.462 *	0.359 *	0.59 *
16 Job Creation Capacity	0.333 *	0.487 *	0.333 *	0.41 *	0.641 *	0.667 *
17 Project Innovation	0.333 *	0.641 *	0.282 *	0.333	0.359 *	0.564 *
18 Cultural Activities	0.385 *	0.538 *	0.282 *	0.436 *	0.282 *	0.333
19 Service Industry Activity	0.103	0.436	0.154	0.333	0.256	0.436
20 Construction and Material Efficiency	0.231	0.462 *	0.256 *	0.333	0.333	0.513

Indicator/Element	Lingotto Before Transformation	Lingotto After Transformation	Dora River Industrial Zone Before Transformation	Dora River Industrial Zone After Transformation	OGR Before Transformation	OGR After Transformation
21 Energy Savings	0.103	0.41	0.128	0.359	0.154	0.487
22 System Circularity	0.051	0.256 *	0.077	0.256	0.179	0.359
23 Structural Compatibility	0.154	0.538 *	0.179	0.385	0.282	0.436
24 Minimal Intervention	0.051	0.487 *	0.077	0.308	0.103	0.59 *
25 Reversibility	0.179	0.538 *	0.231 *	0.538 *	0.41 *	0.615 *
26 Multidisciplinary Cooperation	0.051	0.436 *	0.103	0.41 *	0.385 *	0.436
27 Interdisciplinary Cooperation	0.128	0.256	0.154	0.308	0.231	0.308
28 Transdisciplinary Cooperation	0.103	0.487 *	0.154	0.154	0.205	0.564 *
29 Planning Tool Utilization	0.026	0.205	0.077	0.256	0.103	0.641 *
30 Preservation Awareness	0.128	0.282	0.128	0.282	0.231	0.41
31 Multi-Level Participation (Local)	0.154	0.256	0.154	0.308	0.59 *	0.692 *
32 Multi-Level Participation (Regional)	0.179	0.359	0.179	0.385	0.256	0.795 *
33 Multi-Level Participation (Global)	0.051	0.282	0.103	0.282	0.256	0.718 *
34 Identity Recognition	0.128	0.333	0.128	0.128	0.667 *	0.667 *
35 Social Inclusion	0.333 *	0.359	0.282 *	0.564 *	0.333 *	0.436
36 Collective Growth	0.179	0.359	0.231 *	0.333	0.231	0.359
37 Community Cooperation	0.205	0.333	0.256 *	0.333	0.359 *	0.462 *
38 Participation Process (Consultation)	0.231	0.282	0.205	0.564 *	0.41 *	0.487
39 Participation Process (Co-Creation)	0.103	0.205	0.128	0.59 *	0.154	0.59 *
40 Participation Process (Autonomy)	0.026	0.333	0.077	0.513 *	0.179	0.59 *

Source: Drawn by the author.

Secondly, in terms of key collaborative elements, the three cases exhibit differences in high-centrality elements: OGR is centered on "innovation/culture," Dora Park focuses on "environment/community," while Lingotto emphasizes "economy/image." This reflects the differences in project functional positioning, which lead to different axes of synergy. However, there are also common key elements: for example, "cultural compatibility" played a crucial role in all three projects—whether it was preserving industrial structures for exhibition and education (Dora Park), transforming industrial buildings into artistic spaces (OGR), or maintaining the industrial architecture itself as a city landmark (Lingotto), cultural elements formed synergistic connections with other dimensions. Similarly, elements like "employment rate" and "job creation potential" improved after transformation in all three cases, albeit to varying degrees, and showed a positive correlation with the successful operation of the projects, indicating that adaptive reuse projects require a certain degree of economic self-sufficiency to sustain long-term benefits.

When comparing the collaborative networks across the three cases, certain key elements consistently exhibited high centrality and network connectivity, emerging as the most representative indicators of industrial heritage transformation. These core elements primarily include:

"D24: Degree of Minimal Intervention," which emphasizes minimizing alterations to the original industrial heritage during the transformation process to preserve its historical authenticity and spatial integrity while accommodating new functional demands.

"D25: Accessibility," which pertains to transportation accessibility, spatial openness, and the integration of the site into the surrounding urban fabric, directly influencing the public usability and utilization rate of the transformed heritage.

"D26: Degree of Multidisciplinary Collaboration," which reflects the trend of cross-disciplinary cooperation among multiple stakeholders and fields during industrial heritage transformation and serves as a key driver of project innovation and multifunctional development.

"D38–40: Process Participation," covering indicators such as community consultation, co-creation, and self-governance, highlighting the role of public engagement in decision-making and the impact of participatory governance in industrial heritage transformation.

These key elements consistently demonstrated high synergy across multiple cases, indicating that they are critical factors in determining the success of industrial heritage transformation. Future industrial heritage renewal practices should further strengthen these elements to construct a more balanced and efficient collaborative system.

Thirdly, in terms of the magnitude of synergy evolution, OGR experienced the most significant improvement, transitioning from an almost dormant state before transformation to a highly interconnected network; Dora Park followed, initially suffering from complete desolation but later establishing multiple core connections post-transformation; while Lingotto saw relatively smaller changes, as it already had a certain degree of synergy before transformation. The overall density of the collaborative networks in transformed industrial heritage sites increased, but centrality analysis revealed an emerging trend of localized centralization. Before transformation, the synergy between different dimensional elements was relatively fragmented, with few central nodes and a loosely structured core-periphery network. However, after transformation, the collaborative network gradually evolved into a tightly connected structure centered on several key elements, particularly in the dimensions of economic development and social well-being, where certain indicators saw a significant rise in centrality. For instance, in Dora Park's transformation, "degree of reinvestment participation," "population activity level," and "accessibility" emerged as core nodes, demonstrating that the project enhanced its public accessibility and openness.

Although localized centralization enhances the collaborative effects of key elements, it may also lead to the marginalization of certain dimensions. For example, in the transformation of the Lingotto factory, while the core elements of economic development and social well-being were strengthened, the cultural governance and environmental sustainability dimensions showed relatively weaker synergy, indicating that in industrial heritage transformation, further balancing of synergy among dimensions is needed to prevent the marginalization of critical aspects.

Lastly, from the perspective of element correlation analysis, certain universal patterns emerged: economic and cultural dimensions often reinforce each other, as cultural facilities enhance urban attractiveness, thereby generating economic opportunities, while economic investment ensures the sustainability of cultural operations. Environmental improvements strongly correlate with social well-being, as a better environment is a prerequisite for improving residents' health and sense of security. Additionally, multi-stakeholder governance and project effectiveness show a positive correlation, as projects with well-functioning collaborative governance structures tend to have more robust synergy networks. These findings confirm the necessity of comprehensively balancing multiple factors in industrial heritage transformation to achieve integrated development.

Figure 5.8 Summary of Social Network Analysis for Case-Based Synergistic Evaluation

Source: Drawn by the author

In summary, social network analysis has revealed the underlying synergy mechanisms in industrial heritage transformation: successful transformation is not about maximizing a single indicator but rather the result of interdependent and co-evolving elements across various dimensions. Culture, society, economy, and environment function like nodes in a network—only through interconnectivity and mutual reinforcement can the entire system operate effectively. From the analysis of the Turin cases, different types of projects emphasize different aspects of their synergy networks, but several key elements act as pivotal hubs that significantly influence the overall success of the project. In the next section, we will derive strategic insights based on these findings, ensuring that the evaluation results can be directly translated into actionable design and planning strategies, thus closing the loop between theory and practice.

5.5 Design Strategy Synthesis

By comparing and analyzing the element-based synergy network structures of the three major industrial heritage redevelopment projects, a group of indicators consistently occupying high-synergy positions across the cases can be identified, based on changes in centrality and network connectivity before and after transformation. Through structural classification and value refinement, five categories of typical, guiding systemic synergy strategies are derived, corresponding to five key dimensions in the transformation process: functional restructuring, cultural integration, ecological embedding, place identity, and governance innovation.

Table 5.6 Derivation of Synergistic Strategies

Synergy Strategy Dimension	Key Elements	High-Synergy Indicators	Key Features and Characteristics	Representative Case Data (Examples)
1. Mixed Functions and Flexible Space	Functional integration, adaptive reuse, spatial flexibility	D06 (Accessibility), D03 (Knowledge Agglomeration), D16 (Employment Potential), D14 (User Activity), D17 (Project Innovation), D25 (Reversibility)	Significant increase in post-transformation centrality; promotes shift from single-use to multifunctional, open structures	D06 reaches 0.744 in Lingotto; D16 and others all exceed 0.51

2. Cultural and Innovation-Driven Core	Structural integration, cultural expression, institutional communication	D23 (Structural Compatibility), D02 (Cultural Wellbeing), D18 (Cultural Activity), D05 (Management Communication), D11 (Strategic Integrity)	Features typical of institutional-cultural synergy; supports simultaneous spatial reconstruction and cultural renewal	D23 reaches 0.59 in OGR; D11 ranges from 0.59 to 0.744 in all three cases
3. Ecological Embedding and Circular Systems	Environmental performance, eco-infrastructure, green policy tools	D22 (System Circularity), D21 (Energy Savings), D20 (Material Efficiency), D29 (Planning Instruments), D30 (Financing Instruments)	Green performance transformed into systemic modules; synergy enables ecologically embedded transformation mechanisms	In OGR, D22 reaches 0.641; D21 reaches 0.59
4. Place Identity and Historical Expression	Sense of place, identity, spatial experience	D34 (Sense of Identity), D01 (Cleanliness and Health), D08 (Regional Safety), D09 (Subjective Well-being), D14, D19 (Service Sector Activity)	Deep integration of historical values and contemporary interpretation; emphasizes experiential and cultural layers	D34 reaches 0.544 in Parco Dora; D14 and D19 show strong activity across cases
5. Multi-Level Participation and Collaborative Governance	Community cooperation, plural participation, institutional synergy	D36 (Collective Growth), D31–D33 (Multi-Level Participation), D38–D40 (Process Engagement), D35 (Social Inclusion), D37 (Community Collaboration)	Establishes multi-dimensional participation mechanisms; elevates from project-level updates to institutionalized platforms	D36 reaches 0.667 in OGR; D39 and D40 in Parco Dora are 0.59 and 0.513 respectively

Source: Drawn by the author.

In analyzing the synergistic network structures across three industrial heritage transformation cases, five typical strategic dimensions were identified based on significant changes in centrality and connectivity of key indicators before and after the interventions. The first of these is mixed functions and flexible space. Indicators such as

D06 (Accessibility), D03 (Knowledge Agglomeration), and D16 (Employment Potential) showed notable increases in centrality during the post-transformation phase in all three cases, with values generally exceeding 0.51. In the Lingotto project, D06 reached as high as 0.744, indicating its crucial role in enhancing multifunctional spatial dynamics. Meanwhile, D14 (User Activity) and D17 (Project Innovation) maintained consistently high levels of synergy, and while D25 (Reversibility) performed modestly in Parco Dora, it was considerably stronger in OGR and Lingotto. This highlights the stable synergistic relationship between spatial adaptability and functional integration, underscoring the importance of ensuring flexibility and adaptability through coordinated elements to facilitate the shift from single-purpose industrial spaces to multifunctional, open-ended structures.

The second strategic dimension centers on culture and innovation as core drivers. D23 (Structural Compatibility) saw substantial increases in centrality across all cases following transformation—rising from 0.231 to 0.538 in Parco Dora and reaching 0.59 in OGR—indicating an enhanced capacity for structural integration. In parallel, D02 (Cultural Wellbeing), D18 (Cultural Activity), and D05 (Management Communication) maintained mid-to-high weights, with D05 reaching 0.513 in both Parco Dora and OGR. This suggests a correlation between institutional communication and cultural expression. Moreover, D11 (Strategic Integrity) consistently appeared in the high-synergy range (0.59–0.744), reflecting a resonant alignment between strategic clarity and structural adaptability. This strategy therefore promotes the integration of cultural resources with institutional dissemination mechanisms to support the co-evolution of spatial reconstruction and cultural programming.

The third dimension emphasizes the fundamental role of environmental quality in delivering social benefits. Post-transformation, D22 (System Circularity) achieved high centrality scores across the board—0.462 in Parco Dora, 0.641 in OGR, and 0.487 in Lingotto—demonstrating the integration of resource conservation and circularity principles into the core of redevelopment processes. D21 (Energy Savings) and D20 (Material Efficiency) also demonstrated strong synergy, with D21 reaching 0.59 in OGR. Although D29 (Planning Tools) and D30 (Financing Instruments) showed slightly lower weights, they provided consistent support as institutional mechanisms for the green transition. This suggests that environmental performance metrics have evolved from passive evaluative indicators into proactive systemic components, enabling an embedded model of ecological infrastructure within the broader transformation strategy.

The fourth strategy involves the contemporary articulation of historical value. After transformation, D34 (Sense of Identity) achieved a centrality of 0.544 in Parco Dora and remained strong in the other two cases, suggesting a sustained synergy between historical values, place identity, and contemporary reinterpretation. This indicator is complemented by D01 (Cleanliness and Health), D08 (Regional Safety), and D09 (Subjective Well-being), which form the sensory basis for users' spatial experiences, while D14 (User Activity) and D19 (Service Sector Activity) reveal the role of emerging industries in reshaping public interaction with space. Together, these factors demonstrate how the reinterpretation of historical significance and innovative contemporary uses can merge to support the reconstruction of industrial heritage through both material transformation and cultural redefinition.

The fifth and final strategic dimension highlights multi-level participation and collaborative governance. Among all cases, D36 (Collective Growth) consistently showed high centrality and network connectivity, reaching 0.554 in Parco Dora, 0.667 in OGR, and above 0.538 in Lingotto. This confirms the foundational importance of shared development capacity in the evolution of industrial heritage projects. Indicators such as D31–D33 (Multi-Level Participation) and D38–D40 (Process Engagement) also increased significantly in Parco Dora and OGR, forming a participatory network that spans local to global scales and includes multiple actors and phases. In Parco Dora, for example, D39 (Co-Creation Participation) and D40 (Autonomous Participation) reached 0.59 and 0.513 respectively, emphasizing the effective role of public engagement mechanisms. Furthermore, D35 (Social Inclusion) and D37 (Community Cooperation) reinforced the foundation for neighborhood-level governance collaboration. Altogether, the synergistic system centered on "collective growth" not only enhanced the social adaptability of each project but also drove a deeper transition from technical updating toward institutionalized cooperation, forming an emergent governance framework rooted in multi-level and multi-dimensional co-production.

These findings directly inform the design strategies proposed in the following chapter. For instance, the strategic importance of "multi-level participation" is addressed through concrete proposals to build participatory platforms and facilitate collaborative governance, while the emphasis on "culture-driven transformation" translates into recommendations for leading regeneration efforts through cultural facilities and programming. This closes the evaluative loop by translating assessment outcomes into actionable design strategies that can guide real-world planning and implementation.

6 Design of Mirafiori Industrial Site Based on Element System Synergy

6.1 Industrial Heritage Transformation Strategies Aimed at Element System Synergy

To enable the synergistic transformation of multi-element systems in the renewal of industrial heritage sites, this study builds upon the results of the collaborative evaluation model to propose a tool-oriented system of design strategies. Grounded in five synergistic logics—functional integration, cultural reconstruction, green infrastructure, identity formation, and pluralistic governance—the strategy framework outlines nine thematic guidelines and a total of 45 spatial intervention measures, systematically addressing the transformation from normative evaluation to operational implementation.

Specifically, Strategy 1: Reversibility Synergy emphasizes the generation of mixed functions and spatial diversity. It advocates techniques such as modular assemblage, vertical integration, and multifunctional outdoor spaces to enhance site efficiency and spatial activation potential. Strategy 2: Structural Compatibility Synergy focuses on embedding cultural narratives into spatial programming, encouraging diverse formats such as hybrid exhibition spaces, cultural landmarks, and open curatorial mechanisms. Strategy 3: Systemic Carrying Capacity Synergy targets the integration of green infrastructure, proposing progressive environmental interventions ranging from soil remediation and ecological corridors to stormwater management and vegetative co-construction with existing relics. Strategy 4: Identity Recognition Synergy stresses the fusion of historical memory with contemporary functions through spatial storytelling, symbolic heritage recoding, and multi-modal displays to reinforce a strong sense of place. Lastly, Strategy 5: Collective Growth Synergy derives from multi-level governance mechanisms, constructing a deliberative spatial framework that includes co-creation platforms, public forums, consensus-building narrative axes, and shared visual identity elements.

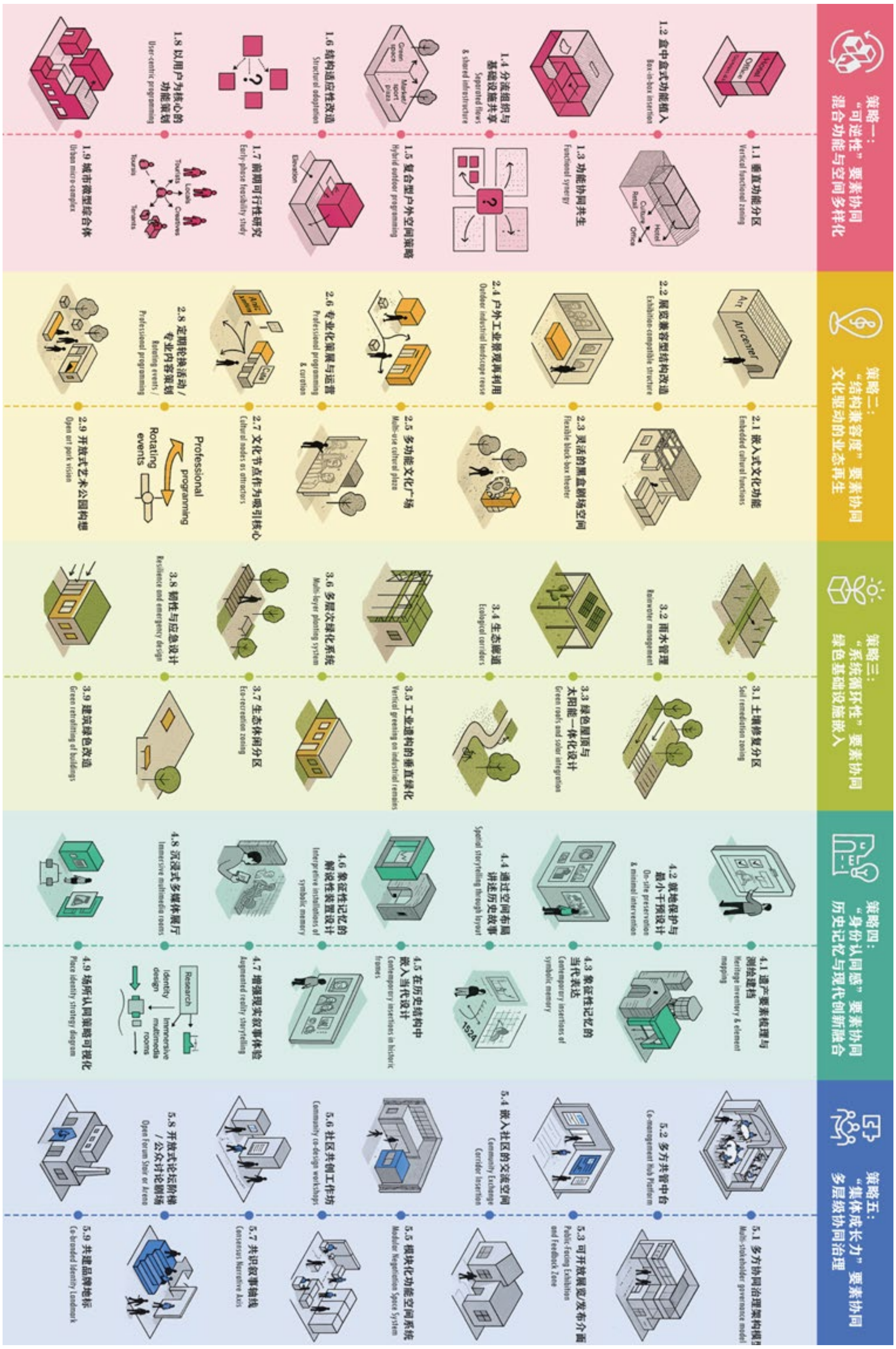


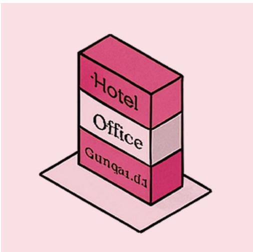
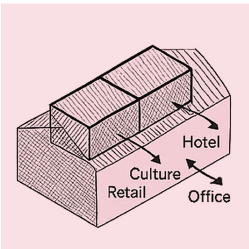
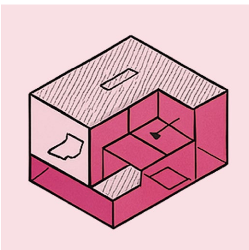
Figure 6.1 Strategy Toolkit for Industrial Heritage Transformation

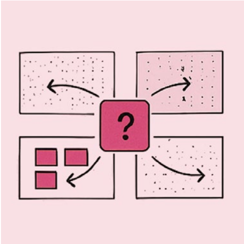
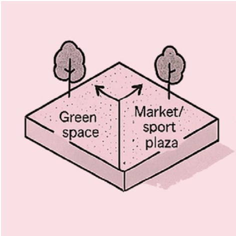
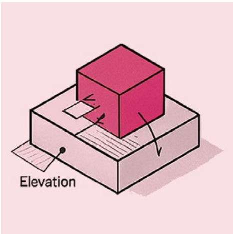
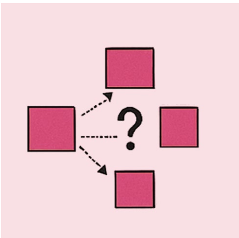
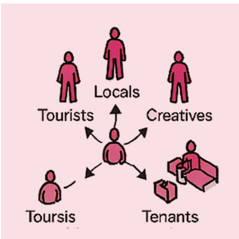
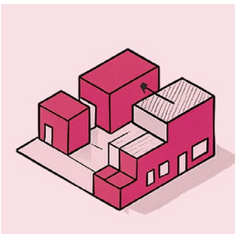
Source: Drawn by the author

6.1.1 “Reversibility” Element Synergy: Mixed-Use Functionality and Spatial Diversity

In the design practices oriented toward industrial heritage transformation, flexibility and adaptability have emerged as key directives for responding to uncertain urban demands and diverse usage scenarios. Based on the results of the synergistic network analysis, elements related to reversibility—such as D25 (Reversibility), D06 (Accessibility), and D16 (Employment Potential)—demonstrate consistently high centrality and extensive connectivity across multiple case studies. This indicates the relevance of proposing “mixed functions and spatial diversification” as a primary forward-looking design strategy. At its core, this strategy seeks to guide highly elastic spatial and functional configurations through the logic of element synergy, thereby enabling the establishment of adaptive redevelopment pathways for future-oriented transformation.

Table 6.1 Transformation Strategies Guided by the Synergy of “Reversibility”-Related Elements

Strategic Pathway	Diagram	Design Logic and Key Operational Points	Case Application and Extended Explanation
Vertical Functional Zoning		Leverages the vertical clearance of industrial buildings to separate upper and lower functions, achieving precise alignment between spatial volume and functional demands.	In OGR, upper levels are allocated for exhibition and performance, while lower levels accommodate meetings and service facilities.
″Box-in-Box″ Functional Insertion		Introduces new functions by embedding modular structures within historical spaces, preserving authenticity while enhancing flexibility.	Commonly employs prefabricated steel modules that allow reversible removal, such as for small galleries or work pods.
Synergistic Coexistence of Functions		Designs circulation to guide interaction between functions and user groups, strengthening cross-program synergy among commerce, culture, and office uses.	In Lingotto, the integration of retail, performance, and office functions fosters user flow and prolonged engagement.

Diverted Circulation and Infrastructure Sharing		Implements logistics-path separation and centralized infrastructure systems (HVAC, water, power, waste), promoting efficiency and energy savings.	Includes shared equipment rooms, energy hubs, and service corridors to optimize long-term maintenance and operations.
Hybrid Outdoor Space Strategies		Designs “elastic zones” to accommodate gatherings, leisure, markets, and performances in adaptable settings.	In Parco Dora, open plazas serve as leisure areas on weekdays and transform into markets or stages during events, enabling “empty - full” transitions.
Structural Adaptation Retrofit		Uses selective elevation, cut-throughs, and rooftop extensions to retrofit old structures, balancing architectural integrity with functional modernization.	In OGR’ s west wing, a double-height atrium and glass curtain wall introduce natural light and enhance the exhibition experience.
Preliminary Feasibility Studies		Establishes intervention boundaries between “modifiable” and “preserved” zones through structural diagnosis and user analysis.	Typical methods include stress testing, behavioral observation, and environmental simulation (e.g., ventilation and daylight).
User-Centered Functional Programming		Tailors spatial content to the needs of different user groups to increase place attachment and daily engagement.	Example: a micro-community formed by maker studios, skate plaza, and art bookstore attracts long-term local users.
Urban Micro-Complex Construction		Builds modular, recombinable composite units that support both independent operation and integrated insertion, allowing for adaptability and scalability.	These spaces work like “urban puzzle pieces,” responding to evolving city needs and facilitating phased functional transitions.

Source: Drawn by the author.

From a design perspective, this strategy first emphasizes vertical functional zoning and box-in-box functional insertion as key structural approaches. Given the typically generous floor-to-ceiling heights in industrial buildings, different functional modules—such as offices, hotels, and cultural-commercial units—can be stacked vertically to achieve a precise match between usage logic and spatial hierarchy. The “box-in-box” strategy, on the other hand, allows new programmatic volumes to be embedded within the existing structural envelope, enabling swift shifts in spatial usage without compromising the architectural authenticity. For instance, in the renovation of the OGR workshops, prefabricated steel-frame interior shells were introduced to house small-scale exhibition and meeting units, thus preserving the historical character of the site while offering high degrees of flexibility.

Functional synergy is reflected not only in structural interventions, but also in the programmatic logic of functional co-existence. The introduction of functionally synergistic coexistence and shared infrastructure mechanisms enables dispersed uses—such as office, cultural, and commercial programs—to support and feed into one another, forming an internally cohesive operational loop. In the case of Lingotto’s transformation, the newly added cultural exhibition spaces and shopping mall are strategically connected through circulation that encourages cross-flow of visitors, thereby enhancing overall vibrancy. At the same time, utility and service components—such as logistics routes and energy nodes—are consolidated through a unified system, significantly improving operational efficiency and resource performance.

At the outdoor level, the “reversibility” strategy extends into the design of hybrid open spaces to enhance spatial elasticity. Traditional open areas in industrial heritage sites often suffer from mono-functional landscape treatment. This strategy proposes the creation of “elastic zones” as multi-scenario mediators—combining green spaces, marketplaces, temporary installations, and artistic interventions—to subdivide space into fixed and variable parts. These zones serve daily civic use while being readily reconfigurable for gatherings, performances, or pop-up markets depending on the occasion. A prime example is the western plaza of Parco Dora, which functions as a youth-oriented leisure space on regular days and transforms into a light-stage or market area during festivals. Its physical structure enables a high degree of "empty-to-full" reversibility.

Moreover, structural adaptation retrofits constitute another critical component of this strategy. Without altering the primary framework, targeted interventions—such as cut-throughs, elevated levels, and rooftop additions—are introduced to accommodate new programmatic dimensions and technological requirements. In the west wing of the OGR complex, for example, a central atrium was carved out and a full-height glass wall was added to the side elevation, not only releasing vertical visual tension but also optimizing lighting conditions and circulation flow for exhibition use.

The implementation of “reversibility” relies fundamentally on supporting mechanisms in the early design phase. Preliminary feasibility studies ensure a rational basis for flexible interventions. In several projects, physical performance assessments, structural stress analyses, and user demand surveys were conducted to determine which zones are suitable for adaptive reuse and which require preservation, thereby establishing controllable boundaries for flexible design.

In parallel, user-centered functional programming is foundational to ensuring the sustainable operation of functional synergy. Through detailed studies of behavioral patterns and preferences among local residents, creative workers, and tourists, the programming process is guided by the needs of specific communities. This results in a high level of correspondence between spatial form and service provision. For example, in the Parco Dora renewal, a creative makerspace, skateboarding plaza, and independent bookstore were co-located to form a micro-ecological network where everyday consumption and community culture coexist.

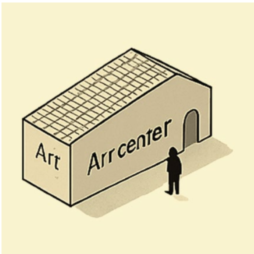
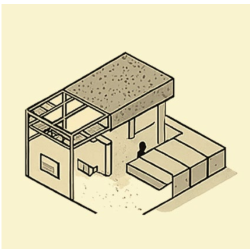
Finally, this strategy proposes an urban micro-complex model, organizing diverse functions and spatial forms through a modular logic. Rather than pursuing large-scale redevelopment, it assembles a system of micro-scale composite units that can function independently or be combined into larger urban configurations. These units are dismantlable, replicable, and upgradeable, offering a spatial template that is highly adaptable to the evolving demands of a flexible city.

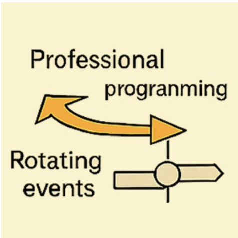
In summary, the “reversibility”-oriented spatial strategy is not a vague appeal for “flexible use,” but rather a coordinated system grounded in structural logic, functional coupling, and institutional support. It offers a systematic design pathway to enable both the long-term evolution and phased functional updates of industrial heritage sites.

6.1.2 "Structural Compatibility" Element Synergy: Culture-Driven Industry Regeneration

In the process of industrial heritage transformation, the spatial adaptability at the structural level and the internal integrative capacity at the cultural level often jointly determine the long-term vitality of regeneration projects. Based on the results of the synergistic network analysis, indicators such as D23 (Structural Compatibility), D05 (Management Communication), and D18 (Cultural Activity) consistently exhibit high centrality and strong connectivity in the post-transformation phases across all three case studies. This pattern supports the identification of the "structural compatibility" element cluster as the foundation of the second core strategic dimension. Building on this, the development of a spatial intervention system can be oriented toward the goal of culture-driven programmatic regeneration, integrating cultural logic with spatial design to guide the adaptive reuse of industrial heritage.

Table 6.2 Transformation Strategies Guided by the Synergy of "Structural Compatibility"-Related Elements

Strategic Pathway	Diagram	Design Logic and Key Operational Points	Case Application and Extended Explanation
Embedded Cultural Functions		Implant high-frequency cultural functions—such as galleries, art shops, and workshops—at nodes with strong openness and accessibility.	In OGR's east wing, a street-corner art entrance hosts book fairs and pop-up markets.
Exhibition-Compatible Structural Retrofit		Enhance spatial exhibition capacity by improving skylighting, surface finishes, and flooring systems.	Installation of track systems and hanging walls to accommodate diverse cultural displays.
Flexible Black Box Theater Spaces		Use convertible stages, modular walls, and multi-directional sets to support immersive and hybrid cultural performances.	At Lingotto, a black-box multifunctional hall enables smooth transitions between cinema, theater, and exhibitions.
Outdoor Industrial Landscape Reuse		Transform old rail lines, water towers, and gas holders into landscape features to enhance visual identity and functional adaptability.	The gas holder frame at Parco Dora hosts night music festivals and art installations.

Multi-Functional Cultural Plazas		Establish open squares at transitional industrial interfaces for use as markets, performance venues, and gathering spaces.	Deploy low-density mobile facilities to retain spatial openness and encourage event activation.
Professional Curation and Operations		Introduce interdisciplinary cultural management teams to systematize programming and foster ongoing co-creation.	OGR collaborates with universities and foundations to deliver seasonal themed content.
Cultural Nodes as Attraction Cores		Cluster small-scale cultural activities to create high-engagement social nodes and guide pedestrian flow.	Art markets and performance corners are arranged around courtyards to form vibrant cultural hubs.
Rotating Programming Mechanisms		Develop sustainable content cycles through a “theme－time－space” matrix approach.	Seasonal exhibitions, open days, and evening events at OGR create a continuous rhythm of engagement.
Open-Air Art Park Vision		Create an accessible, interactive, and evolving open art space that blends nature, culture, and public life.	A multi-scalar, boundary-blurring cultural landscape system emphasizes everyday accessibility and participation.

Source: Drawn by the author.

This strategy begins by emphasizing the embedding of cultural functions within existing industrial structures to activate the site’s latent public potential and collective memory. The introduction of embedded cultural programs requires careful identification of historically permeable spatial interfaces and lines of sight, prioritizing highly open and externally connected nodes for the insertion of high-frequency, community-linked uses such as galleries, workshops, and art bookstores. For instance, in the eastern wing of the OGR workshop, an independent, street-facing art entrance was created to enhance its interaction with the urban fabric. This spatial gesture successfully attracted events with high public engagement, including independent art book fairs and pop-up music markets.

Building on this foundation, the physical structure itself must be capable of supporting exhibition uses. The strategy of exhibition-compatible structural retrofit proposes a series of technical modifications—such as improved skylighting, replacement of surface materials, and strengthening of floor loading capacity—to accommodate a range of display formats and increase the spatial support capacity for cultural programming. For more complex performance scenarios, the design of flexible black box theater spaces is introduced. These spaces use modular wall systems, convertible stage infrastructure, and multidirectional set arrangements to allow seamless transitions across formats including theater, forums, dance classes, and video production. This concept of "structure-as-infrastructure" is exemplified in the multifunctional hall at Lingotto, where a black-box layout with suspended lighting rails and movable partitions enables rapid reconfiguration from film screenings to immersive performance art.

Cultural space, however, is not limited to the indoors. The strategy of outdoor industrial landscape reuse focuses on the reinterpretation and public reprogramming of industrial remnants such as tracks, water towers, and chimneys. These are adapted through lighting installations, climbing structures, or performance backdrops to elevate their symbolic and functional resonance, turning them into natural containers for cultural activities. A notable example is the gas holder framework in Parco Dora, which has been converted into a visual urban landmark and functional venue for nighttime concerts and large-scale installations.

At a broader organizational level, multi-functional cultural plazas repurpose residual or marginal zones within industrial sites into new public gathering nodes. Typically situated at the transitional interface between factory buildings and adjacent streets, these plazas are designed to guide visitor flows into central exhibition areas while retaining openness and activation potential through the use of low-density elements such as sculptures, fountains, and market stalls. When coupled with thoughtful programming, such spaces can form cultural attraction nodes with continuous engagement capacity. In the case of Parco Dora, several small cultural clusters are organized around a steel-framed courtyard to host recurring weekend artisan markets and open-air film screenings, forming a vibrant and responsive cultural space scenario.

A prerequisite for structural compatibility is the professionalism and continuity of cultural operations. Thus, this strategy also underscores the importance of establishing a mechanism for professional curation and operation, recommending the introduction of interdisciplinary cultural management teams. Through systematic content planning, regular content updates, and long-term community co-creation mechanisms, such teams enhance the self-organizing capacity and operational stability of cultural systems. In OGR, this approach is realized through partnerships with universities and cultural foundations in Turin, enabling the implementation of a “season–theme–space” rotation model for programming renewal.

Ultimately, this strategy envisions the creation of an open-air art park that integrates cultural activity, natural landscape, and urban public life. Departing from traditional enclosed exhibition modes, this park concept aims to establish an art-led spatial system that is accessible, interactive, and evolving—a boundary-free, cross-scalar cultural infrastructure embedded within industrial heritage, shaping a new ecology of urban life driven by cultural engagement.

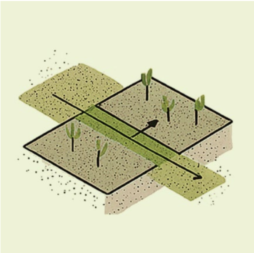
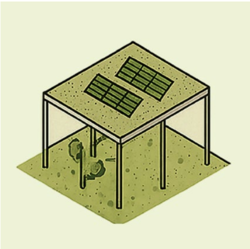
In summary, the “structural compatibility”-oriented design strategy not only addresses the fundamental functional reconfiguration needs of industrial space reuse, but also, through the deep synergy between structure and cultural content, revitalizes the site's capacity for cultural production and social participation. It therefore provides a critical pathway for achieving sustained spatial activation and ecologically integrated operations.

6.1.3 "System Circularity" Element Synergy: Integration of Green Infrastructure

In response to the widespread issues of environmental degradation, structural aging, and ecological fragmentation commonly found in industrial heritage sites, the deep integration of green infrastructure emerges not only as a core strategy for enhancing ecological performance, but also as a vital pathway for establishing systemic circularity and strengthening urban resilience. According to the results of the synergistic network analysis, indicators such as D22 (System Circularity), D21 (Energy Savings), and D20 (Construction and Material Efficiency) all exhibit significant increases in centrality during the post-transformation phase across the three studied projects. This indicates that green elements are playing an increasingly active role in the network, with stronger systemic linkages and synergistic impacts.

Based on this finding, a system-circularity-oriented design strategy is proposed, which emphasizes the ecological embedding of infrastructure as a means to construct multi-scalar and sustainable operational mechanisms. This strategy focuses on transforming green performance from a passive environmental metric into an actively configured structural logic that integrates landscape, energy, and resource systems within the broader framework of industrial heritage regeneration.

Table 6.3 Transformation Strategies Guided by the Synergy of "System Circularity"-Related Elements

Strategic Pathway	Diagram	Operational Logic and Design Focus	Case Example and Application Scenario
Soil Remediation Zoning		Divide the site into remediation, planting, and restricted-use zones based on pollution levels; adopt differentiated treatment strategies.	In the Zeppelin Industrial Park, areas are zoned for ecological remediation, restricted access, and planting.
Rainwater Management		Introduce infiltration, collection, and filtration facilities to establish an on-site water cycle.	At OGR, detention ponds combined with green buffer strips allow dual use for storm drainage and irrigation.
Green Roof and Solar Integration		Combine rooftop greening with solar energy generation to improve energy efficiency while creating leisure spaces.	Lingotto' s rooftop was transformed into a composite area with solar panels and planted platforms.
Ecological Corridors		Link internal ecological nodes to the urban green network, integrating habitat, circulation, and microclimate functions.	In Parco Dora, an ecological trail along the former railway line connects the eastern and western zones.
Vertical Greening of Industrial Structures		Preserve steel frames as climbing supports to form vertical ecosystems and improve visual and climate performance.	At OGR, steel structures were retained for vine growth, creating green façades with thermal benefits.

Multi-Layered Planting Systems		Combine trees, shrubs, and groundcover to build a ground-level ecological system with filtration, shading, and habitat functions.	Often combined with vertical greening to form a three-dimensional ecological system.
Eco-Recreational Zones		Design meditative gardens, amphitheaters, and permeable paving to promote low-carbon public behavior.	Provides "accessible, dwellable, and adaptable" natural experience spaces.
Resilience and Emergency Design		Integrate shelters, emergency lighting, and independent water supply to enhance disaster preparedness.	Can serve as temporary shelters or functional conversions during extreme weather events.
Green Building Retrofit		Apply insulation, natural ventilation, and renewable materials to create closed-loop green operations.	At Lingotto's conference center, geothermal pumps and reused bricks were implemented in its renovation.

Source: Drawn by the author.

The foundation of this strategy lies in the identification and response to site-specific environmental risks. The establishment of soil remediation zones provides the ecological precondition for broader green infrastructure interventions. Industrial heritage sites often face issues such as heavy metal contamination and residual hydrocarbons. Design responses involve zoning the site based on contamination levels, which guides the spatial deployment of different remediation approaches. For example, in the redevelopment of the Zollverein Industrial Complex in Essen, Germany, preliminary soil testing informed the division of the site into ecological restoration zones, restricted-use areas, and ecological planting zones, thereby providing a scientific and sustainable foundation for subsequent greening efforts.

Complementing this approach is the integration of a rainwater management system, which not only improves stormwater drainage efficiency but also enables on-site water circulation through surface infiltration, collection basins, and filtration greenbelts. In the OGR project, a combined system of underground retention tanks and surface-level bio-swales helps mitigate flood risk during extreme rainfall while supplying seasonal irrigation for landscape maintenance.

At the upper structural level, the green roof and solar integration strategy merges ecological energy systems with architectural envelopes. This dual-use model enhances building performance while offering new leisure resources. In the rooftop renovation of the Lingotto complex, the original concrete roof was transformed into a walkable green platform combined with solar panels, simultaneously serving as a landscaped area and as an independent energy source for lighting in exhibition spaces.

The creation of ecological corridors serves as a structural backbone linking internal ecological nodes to the surrounding urban green network. These corridors perform multiple roles, including species migration, microclimate regulation, and pedestrian connectivity. In the northern section of Parco Dora, an ecological trail laid along a former railway bed connects the eastern riverside greenbelt with the western cultural plaza, ensuring ecological continuity across functional zones.

At the facade and structural frame level, the combination of vertical greening on industrial remnants and multi-layered vegetation systems forms a three-dimensional ecological base. In OGR, preserved steel frameworks are repurposed as climbing supports for vine species, creating vertical green screens, while the ground level is planted with a mixed assemblage of trees, shrubs, and groundcover, enhancing both aesthetic value and microclimate regulation.

The establishment of eco-recreational zones further expands the social functionality of green space, embedding ecological strategies into everyday community life. Facilities such as permeable paving, open-air amphitheaters, and meditation gardens encourage low-carbon behaviors and provide accessible spaces for nature-based public engagement.

To improve preparedness for extreme climate events and emergencies, the strategy includes resilience and emergency design measures. These include multipurpose structures that can be converted into temporary shelters, emergency lighting systems, and self-sufficient water supply units. This ensures that the site functions as a public space under normal conditions while possessing rapid-response capabilities in times of crisis.

Additionally, green building retrofits form the final link in the ecological loop, enhancing energy efficiency through improved insulation, natural ventilation, and material renewal. In the renovation of Lingotto's conference center, recycled bricks and a geothermal heat pump system were employed, reducing material waste while significantly improving operational performance.

In summary, the system circularity strategy establishes a synergistic mechanism across site remediation, resource cycling, and resilience enhancement. By integrating soil, water, energy, structure, and human activity into a unified ecological logic, it provides both structural support and an ecological pathway for the green transformation of industrial heritage sites.

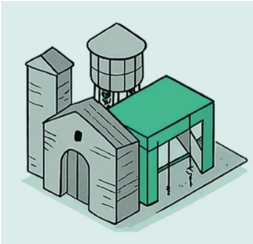
6.1.4 "Sense of Identity" Element Synergy: Fusion of Historical Memory and Modern Innovation

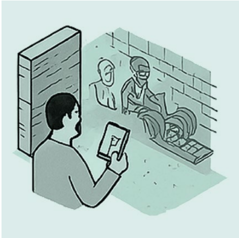
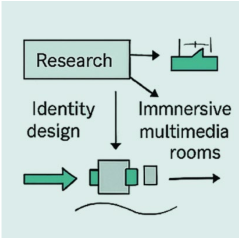
In the spatial regeneration of industrial heritage sites, a central challenge lies in how to integrate contemporary narratives while preserving the historical memory of place, thereby fostering collective recognition and cultural continuity. The goal is not only to conserve physical structures but to establish a shared sense of identity that resonates across diverse publics. Results from the synergistic network analysis highlight this priority: indicators such as D34 (Sense of Identity), D01 (Cleanliness and Health), and D08 (Regional Safety) showed sustained increases in synergy weights in the post-transformation phases of both the Parco Dora and OGR workshop projects. In particular, D34 reached a centrality score of 0.544 in Parco Dora, underscoring the importance of embedding identity-building mechanisms into spatial strategies as a key factor for unlocking the long-term value of industrial heritage.

In response, this paper proposes a set of identity-oriented spatial strategies, emphasizing a design approach rooted in historical interpretation and extended through contemporary expression and digital mediation. The aim is to construct spaces of identity that are legible, experiential, and reproducible—places where memory becomes accessible and meaning is actively co-produced through spatial, cultural, and technological layers.

Table 6.4 Transformation Strategies Guided by the Synergy of "Sense of Identity"-Related Elements

Strategic Pathway	Diagram	Operational Logic and Design Focus	Case Example and Application Scenario

Heritage Element Survey and Digital Archiving		Digitally scan, map, and tag industrial components, spatial textures, and equipment relics to establish a heritage database.	Pre-renovation surveys and modeling conducted for Parco Dora and OGR.
In-situ Preservation and Minimal Intervention		Retain original components and textures to reveal the “traces of time”; emphasize material authenticity and structural integrity.	OGR workshops preserved oil-stained floors and rusted steel beams.
Contemporary Interpretation of Symbolic Memory		Use contemporary art installations to reframe historical imagery; avoid literal reproduction and focus on semantic reconstruction.	Parco Dora’s “Soundwave Passage” and reinterpretation of industrial symbols.
Storytelling through Spatial Layout		Build immersive narrative experiences via exhibition rhythm and movement paths, turning space into a “storyteller.”	The OGR industrial memory exhibit uses a “dark-to-light” spatial logic.
Contemporary Insertion within Historic Structures		Integrate new functions into existing structures through nested or interlocking strategies to preserve form while enhancing usability.	At Lingotto, a former freight elevator shaft is repurposed as an information pillar for maker spaces.
Interpretive Installations of Symbolic Memory		Create open-ended installations that invite public imagination and plural readings, avoiding one-directional messaging.	Multimedia walls and audiovisual interaction units in OGR.

Augmented Reality (AR) Narrative Experience		Use AR to overlay historical information onto present scenes, enabling real-time reading of site memory.	AR simulations of worker operations used in the OGR project.
Immersive Multimedia Exhibition Halls		Combine projection, soundscapes, and spatial design to form sensory theaters that expand narrative expression.	OGR’s multimedia galleries and digital interaction rooms.
Visualization of Identity Strategies		Represent identity-building mechanisms via maps, spatial tags, and interactive diagrams to enhance public engagement.	“Identity mapping” used in participatory design and community co-creation processes.

Source: Drawn by the author.

This strategy begins with the systematic survey and digital archiving of heritage elements, which forms the foundation for any memory-based spatial intervention. The process of “heritage element documentation” requires the design team to analyze industrial components, legacy equipment, structural remnants, and spatial textures across multiple layers. Through scanning, mapping, 3D modeling, and tagging systems, key elements are digitally recorded and spatially annotated, providing a structured basis for future preservation and exhibition planning.

In terms of preservation, the strategy of in-situ conservation and minimal intervention prioritizes the authenticity of material and site specificity. By retaining rusted structural elements, exposed frameworks, or construction traces, the design creates perceptible layers of time and place. In the main hall of the OGR workshops, preserved riveted steel beams and oil-stained floors form a critical part of the spatial narrative, allowing visitors to physically engage with the industrial past through texture, color variation, and scale.

To endow historical narratives with contemporary relevance, the strategy of symbolic memory through contemporary expression encourages the reinterpretation of cultural motifs, industrial symbols, or collective memories via abstract installations and modern media. These interventions avoid literal reconstruction, instead opting for material translation and semantic reframing to create new spatial narratives. For instance, in Parco Dora, repurposed industrial pipelines were artistically transformed into a “Soundwave Passage,” symbolizing the rhythm of industrial labor and collective urban memory while also stimulating public interaction.

The strategy of storytelling through spatial layout organizes movement, exhibit rhythm, and sequencing to guide visitors through an immersive reconstruction of site memory. Here, space becomes not just a vessel for display but a narrative device in itself. The industrial memory exhibition in OGR, for example, utilizes a spatial sequence “from darkness to light” to metaphorically represent the transition from history to the present, prompting a perceptual shift from distance to intimacy, from otherness to personal identification.

Contemporary insertion within historical structures reflects a respectful and adaptive reuse of existing buildings. New functions are integrated into the old framework through nesting, layering, and strategic penetration, enhancing usability while avoiding damage to the original fabric. In Lingotto’s maker space, an old freight elevator shaft was converted into an information pillar, showcasing both current entrepreneurial content and archival imagery—symbolizing a cross-temporal narrative fusion.

Additionally, interpretive installations for symbolic memory utilize legible but open-ended spatial artifacts that invite visitors to actively construct meaning, encouraging personalized readings of history rather than imposing fixed narratives. This approach respects the multiplicity of memory and avoids unidirectional official storytelling.

From a technological standpoint, this strategy integrates augmented reality narrative experiences and immersive multimedia exhibition spaces to expand the temporal and sensory dimensions of memory representation. Through AR devices, users can overlay historical content—such as factory workflows or archival images—onto their real-time surroundings, enabling synchronous perception of past and present. Meanwhile, immersive galleries use flexible projection surfaces, surround audio, and emotive soundscapes to create full-sensory narrative theaters that draw visitors into lived memory experiences.

Finally, visualizing identity strategies functions as a design synthesis mechanism. Through spatial diagrams, annotated maps, and “identity curves,” this tactic enables designers, community members, and policymakers to co-understand the spatial distribution and formation of place identity. This facilitates the coordinated development and implementation of identity-building strategies within governance frameworks.

In conclusion, the “sense of identity”-oriented design strategy moves beyond static memorialization and top-down interpretation. It establishes an open system of identification rooted in historical sites, mediated by contemporary expression, and centered on public experience. In doing so, it transforms industrial heritage from something that is merely “visible” into something that is felt, inhabited, and co-created, advancing a deeper cultural reintegration of place.

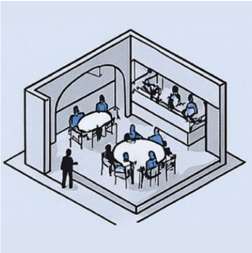
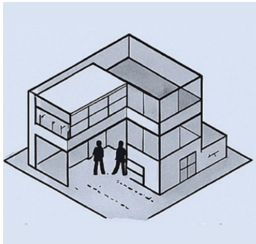
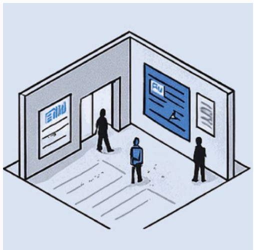
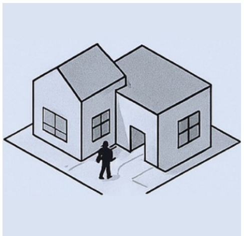
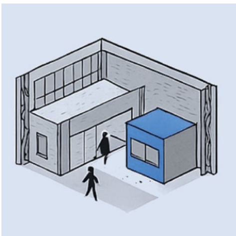
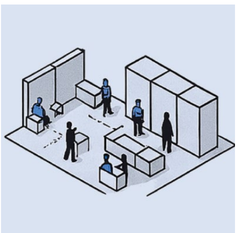
6.1.5 "Collective Growth Potential" Element Coordination: Multi-Level Collaborative Governance

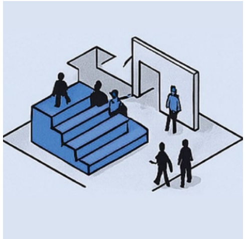
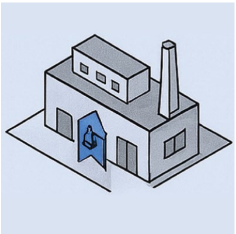
. In the comprehensive process of industrial heritage renewal, the reconfiguration of physical space is often merely the starting point. The long-term success of transformation relies fundamentally on whether a collaborative governance structure can be established—one that involves multiple stakeholders and sustains continuous operations while being deeply embedded in community life. Results from the synergistic network analysis clearly support this assertion: D36 (Collective Growth Capacity) consistently emerged as a high-centrality node in the post-transformation phase across all three representative cases (Parco Dora: 0.554; OGR: 0.667; Lingotto: 0.538). This indicator was tightly coupled with D31–D33 (Multi-Level Participation) and D38–D40 (Process Engagement), forming a highly interconnected collaborative sub-network.

These findings indicate that “collective growth” is not merely about community mobilization or public engagement at the surface level. Rather, it points to a complex, multi-dimensional capacity for spatial governance that can coordinate diverse interests, implement institutional mechanisms, and support co-creation across sectors and scales.

In response, this paper proposes a spatial design strategy oriented around multi-level collaborative governance, with the aim of establishing governance platforms that are open, shared, and consensus-driven. The goal is to transition industrial heritage spaces from passive reuse toward active co-governance, thereby cultivating a socio-spatial ecosystem capable of adaptive, sustainable evolution over time.

Table 6.5 Transformation Strategies Guided by the Synergy of “Collective Growth Capacity”-Related Elements

Strategic Pathway	Diagram	Operational Logic and Design Focus	Case Example and Application Scenario
Multi-Stakeholder Governance Framework		Establish institutional frameworks and visual governance flows; integrate public issue boards and collaboration nodes to promote shared responsibility.	In Parco Dora, an "open governance corridor" features wall-mounted interactive displays for public updates.
Cross-Sector Co-Management Platform		Provide hybrid platforms combining meeting spaces, data access, and operational desks to support long-term and cross-disciplinary collaboration.	The OGR Urban Innovation Center includes a data room, design station, and service counter.
Public Display and Feedback Interfaces		Install information panels, digital screens, and community feedback boards in key corridors and nodes to communicate public issues and updates.	Parco Dora's "public release panel" broadcasts progress reports and collects citizen feedback regularly.
Embedded Community Interaction Spaces		Utilize informal, small-scale spatial elements (e.g., corner seating, message walls, shared courtyards) to encourage resident dialogue.	At OGR, a community gallery and shared gardens foster everyday interpersonal exchanges.
Modular Consultation Space Systems		Construct flexible consultation environments using movable meeting units, opinion walls, and adaptable furniture to support diverse dialogue formats.	Lingotto's exhibition hall uses modular furniture to support variable-scale public consultation.
Community Co-Creation Workshops		Provide physical infrastructure and process facilitation for co-design, prototyping, and intergenerational collaboration.	Parco Dora's "Urban Memory Collage" initiative facilitated collaborative mapping and modeling with locals.

Consensus Narrative Pathways		Organize key public issues along spatial routes, enabling users to experience consensus-building through interactive storytelling.	In Parco Dora, a central axis displays illustrated timelines alongside community comment walls.
Open Forum Staircases / Public Debate Theaters		Design amphitheater-like structures that support speeches, debates, dialogues, and consensus voting to enhance civic expression.	At OGR, the “Civic Theater” staircase hosts public debates on community planning topics.
Co-Created Place Branding Landmarks		Engage multiple stakeholders in naming, visual identity design, and commemorative installations to foster a shared sense of belonging.	At Lingotto, the public façade branding was collaboratively created by local residents and companies.

Source: Drawn by the author.

The primary entry point of this strategy is the construction of a Multi-Stakeholder Collaborative Governance Model, which clarifies the roles and responsibilities among various actors—government agencies, developers, operators, community organizations, and user representatives—through institutional frameworks. Spatial design must reserve physical interfaces for deliberation and expression, such as visual governance diagrams, periodic public issue boards, and interactive policy displays, thereby transforming the built environment into a visible interface for institutional logic. In the renovation of Parco Dora, for instance, the design team collaborated with municipal authorities and citizen groups to create an “Open Governance Corridor,” where wall-mounted interactive installations broadcast updates on collaboration processes and progress, enhancing transparency and public awareness.

Building upon this foundation, the Cross-Sector Co-Management Platform is physically embedded into the site’s core zones to serve as a base for continuous, multi-actor coordination. This platform goes beyond meeting rooms, offering shared workspaces, data visualization tools, and technical support to accommodate frequent interdisciplinary exchanges. At OGR, the Urban Innovation Center embodies this model, integrating a citizen data room, design desks, and public service counters that provide both institutional and spatial support for ongoing collaboration.

To facilitate broader dissemination of public issues, the strategy proposes Open Exhibition and Communication Interfaces integrated into main circulation routes or spatial nodes. These nodes feature physical boards, digital screens, and interactive panels that communicate renovation updates, collect community feedback, and display future planning drafts—creating a “dialogic and updatable” public information mechanism. Complementing this, Community-Embedded Interaction Spaces are introduced at a micro-scale—such as corner seating, shared courtyards, and local galleries—to foster spontaneous everyday encounters and informal collaboration.

To accommodate various forms and scales of collaboration, the Modular Consultation Space System enables spatial reconfiguration via movable meeting units, feedback panels, and dialogue pods. These modular components can be adapted to changing topics and participant configurations at different stages of a project. In Lingotto’s multifunctional exhibition hall, for example, modular furniture allows for seamless conversion between curatorial programming and public deliberation events.

At the content generation level, Community Co-Creation Workshops serve as key platforms for engaging grassroots participation. Spatial configurations must support collaborative activities such as group discussion, prototype fabrication, and materials co-design to ensure iterative co-creation. Parco Dora’s “Urban Memory Collage” project is a strong example, where citizens engaged in map redrawing, model making, and visual archiving to build a cross-generational, pluralistic narrative of community identity.

To enable consensus-building, the strategy introduces Consensus Narrative Pathways, where specific public themes are spatially deployed along linear routes. These paths use visual storytelling, historical fragments, and public commentary boards to allow users to experience the process of memory sharing, issue framing, and consensus formation. Architecturally, Open Forum Staircases or Civic Debate Theaters serve as non-formal platforms for public expression, supporting diverse activities like speeches, impromptu responses, neighborhood debates, and consensus voting. These spaces should be located in semi-public, high-traffic zones and integrated naturally into daily circulation flows.

Finally, the strategy proposes the creation of Co-Created Landmark Symbols as a culmination of the governance process. These landmarks—co-named, co-designed, or embedded with community narratives—act as visual markers of collective authorship, reinforcing place attachment and long-term civic engagement. At Lingotto, for example, the public branding of its façade was collaboratively developed by both local citizens and corporate stakeholders, symbolizing shared stewardship and institutional memory.

In summary, the Collective Growth Capacity Strategy builds a multi-level, sustainable governance structure by integrating institutional logic, spatial infrastructure, and participatory co-creation mechanisms. It shifts industrial heritage regeneration from single-stakeholder redevelopment to co-produced and co-governed urban governance practice.

More broadly, the five strategic systems presented in this study—centered respectively on spatial flexibility, functional integration, ecological embedding, historical-cultural identity, and collaborative governance—are mutually reinforcing and collectively form an integrated transformation framework for industrial heritage renewal. These strategies are grounded in the findings of the synergistic evaluation: governance strategies ensure implementation coherence, cultural and hybrid-functional strategies provide development momentum, environmental strategies support sustainability, and heritage-integration strategies establish site-specific identity.

Crucially, these strategies are both technically actionable and conceptually innovative. In practice, they should be deployed flexibly based on project-specific conditions and priorities. For example, in highly polluted brownfield sites with weak cultural baselines, environmental and governance strategies should be prioritized, with cultural and functional strategies phased in over time. Conversely, for well-preserved architectural assets, cultural and historical strategies may take precedence, supported by functional and governance strategies to ensure operational viability.

When used adaptively, this multi-dimensional strategy set will contribute to achieving the multi-win goals of industrial heritage transformation: economic feasibility, social acceptance, cultural continuity, and environmental regeneration—ultimately breathing new life into old industrial grounds.

6.2 Project Background

The Mirafiori Factory is one of the most significant industrial heritage sites in Turin, with a history tracing back to the early 20th century. Once the largest automobile manufacturing base of Fiat, this factory symbolized Italy's industrial modernization. During the mid-20th century, it reached its production peak, representing the golden age of Turin's automotive industry. However, with the shifting global automotive landscape and the decline of local manufacturing, Mirafiori gradually faced production capacity reductions, aging infrastructure, and underutilized spaces. In recent years, parts of the factory have ceased production, leaving large sections of the site abandoned or inefficiently utilized. This situation not only affects the area's development potential but also presents a critical challenge for urban regeneration and industrial transformation.

This design project is located at the core area of the Mirafiori Factory, covering a total building area of approximately 50,000 square meters, with a primary renovation focus on 12,000 square meters. A key feature of this area is that its western section has already been repurposed by the Politecnico di Torino, converting part of the site into an information technology laboratory. This transformation represents an initial attempt to integrate industrial heritage into the knowledge economy, aligning with higher education and innovation research.

However, the overall transformation of the Mirafiori site remains in its early stages, with several spaces still vacant or lacking a clear functional identity. Therefore, the primary objective of this redevelopment project is to further activate this industrial heritage by establishing it as the Competence Center of Politecnico di Torino, reinforcing the university's competitive positioning while transforming the area into a key hub for urban innovation and high-tech industry development in the future.

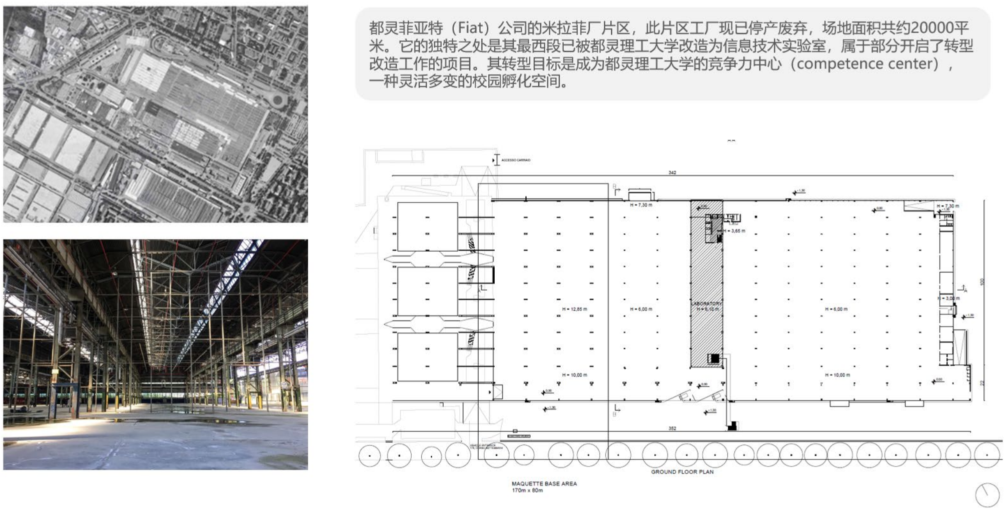


Figure 6.2 Basic Information of the Design Project

Source: Compiled by the author based on data provided by Politecnico di Torino and on-site survey photos.

According to the project planning requirements, this design must accommodate multiple functions, including laboratory and research spaces, office and conference facilities, public service amenities, and open spaces, in order to create an efficient and integrated urban innovation hub.

The laboratory and research spaces constitute one of the core components of this redevelopment. Among them, the heavy-duty laboratory will cover an area of approximately 3,000 square meters and must be located on the ground floor to house large-scale experimental equipment, ensuring both operational safety and convenience. Additionally, the light-duty laboratory, also covering 3,000 square meters, will be designated for research in fields such as computer science, engineering technology, and materials science, meeting the demands of both higher education institutions and corporate innovation initiatives.

The office and conference facilities will provide a high-quality work environment for research teams and business incubators. The office space, spanning approximately 800 square meters, will accommodate multiple academic and industrial teams, fostering close integration between scientific research and industrial applications. Moreover, the conference center, with a seating capacity of 200 people, will serve as a venue for academic forums, technology launches, and industry collaboration meetings, establishing an open and interactive academic and business network.

Regarding public services and supporting facilities, this redevelopment will introduce a range of amenities to support the daily operations of the factory site. These include a total of 700 square meters allocated for rest areas, cafés, a cafeteria, restrooms, and reception areas, catering to the needs of researchers, corporate employees, and visitors. To ensure the efficient transportation and storage of laboratory equipment, the logistics area will feature a dedicated loading and unloading zone, seamlessly integrated with external transportation networks to maintain smooth operations between the laboratory and industrial spaces.

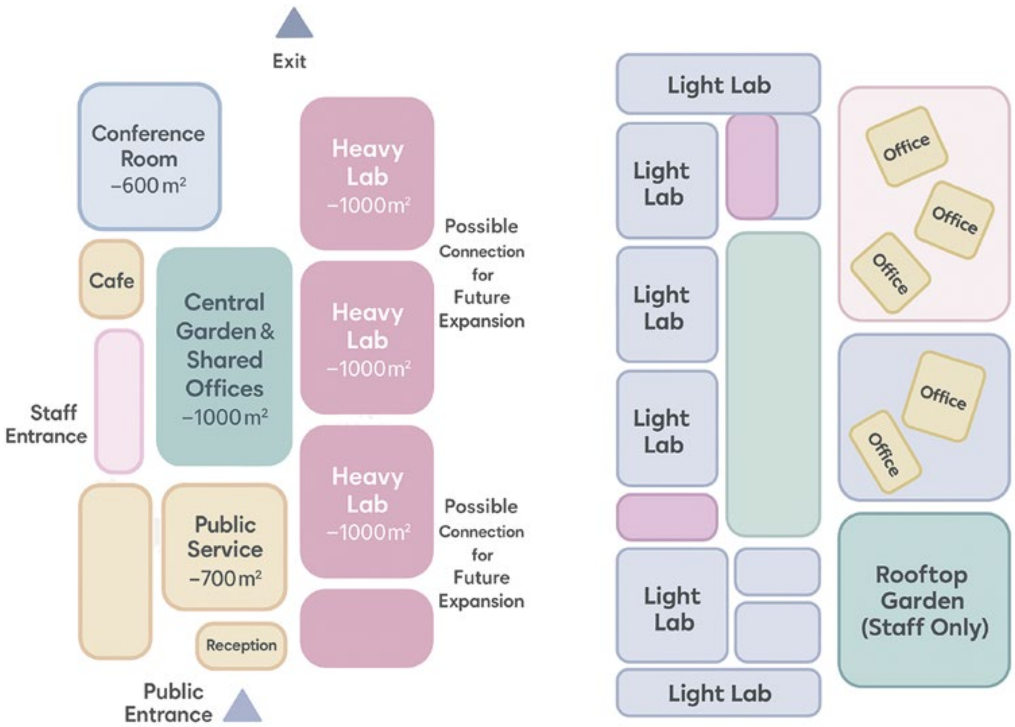


Figure 6.3 Functional Zoning Based on the Design Brief

Source: Compiled by the author

The open space planning aims to enhance the site's public value. A network of green spaces and pedestrian pathways will be arranged throughout the site, providing high-quality interaction and relaxation areas for both researchers and the public. Additionally, an urban exhibition and display area will showcase advancements in industrial heritage preservation and technological innovation, transforming Mirafiori into not only a hub for production and research but also a cultural and knowledge-sharing platform.

During the planning and design process, several key challenges must be addressed through innovative solutions. Firstly, in terms of industrial heritage preservation and adaptive reuse, the design must strike a balance between retaining historical structures and modernizing the space to meet the needs of the current technology industry while preserving the historical and cultural identity of the site. Another major challenge is how to enhance the cultural value of these historic structures, ensuring they serve not only as city landmarks but also as symbols of urban identity.

Secondly, flexible space design is a crucial issue in this planning. How can the laboratory, office, and public service spaces be made adaptable and modular to accommodate future industrial trends? How can a flexible spatial framework be developed to support diverse research and industrial needs while maintaining long-term sustainability? These questions will be central to the project's solutions.

The integration of sustainability and smart building technologies is also critical. Strategies such as passive design solutions, including natural lighting and ventilation, must be employed to achieve energy efficiency targets. These considerations will significantly impact the long-term operational costs and environmental footprint of the site.

Finally, regional synergy is the key to the project's success. How can the redeveloped Mirafiori site be effectively integrated with the adjacent Politecnico di Torino's Information Technology Laboratory, fostering synergies between academic research and industrial innovation? How can urban transportation and public spaces be optimized to strengthen connections between the site and other innovation centers in Turin, creating a globally competitive innovation ecosystem?

The implementation of this project will play a crucial role in transforming Mirafiori from a traditional industrial base into a high-tech innovation hub, providing vital support for Turin's future urban development while serving as a global model for industrial heritage revitalization.

Figure 6.4 Initial Conceptual Framework of the Design

Source: Compiled by the author

6.3 Adaptive Redevelopment Design of the Mirafiori Industrial Complex in Turin Based on Transformation Strategies

6.3.1 Creating "Reversibility": Modular Column-Bay Units

In the redevelopment design of the Mirafiori factory site, the introduction of modular prefabricated column-bay units serves as a crucial strategy for optimizing space utilization and enhancing building adaptability. This design approach leverages the existing massive column structures of the factory, inserting functional modules within the column bays to accommodate building services, work units, exhibition spaces, and various other functions. This strategy not only organizes and optimizes the internal spatial relationships within the building but also ensures that the structure can be dynamically adjusted over time to accommodate changing needs at different stages of development.

The concept of modular units is inspired by the factory's original massive column grid system. Traditional industrial factories typically feature large-span structures to accommodate mass production and heavy machinery, but in the post-industrial transformation, converting such spaces into fixed functional zones often leads to excessively rigid spatial configurations, making it difficult to adapt to long-term evolving demands. To address this, the design fully utilizes the column-bay spaces (10m × 8m × 2m) as insertion zones for functional components, turning them into flexible "containers" adaptable to various functions. By defining standardized module dimensions, the system ensures compatibility with the existing architectural framework while maintaining ease of future modifications and expansions.

Each column-bay unit is designed based on a standard volumetric module of 10m (width) × 8m (height) × 2m (depth), further refined in accordance with the internal spatial proportions of the factory. This modular scale is determined based on the original structural grid of the industrial building, allowing for seamless adaptation within the column-bay spaces while preserving sufficient spatial flexibility for future adjustments and reconfigurations.

According to various functional needs, certain modules may adopt a single-level height (4m), suitable for spaces such as rest areas, bookstores, and mini-meeting rooms. Meanwhile, modules requiring greater spatial capacity—such as exhibition units and vertical circulation units—can be configured as double-height (8m) modules or even larger multi-level combinations to accommodate more complex functional programs.

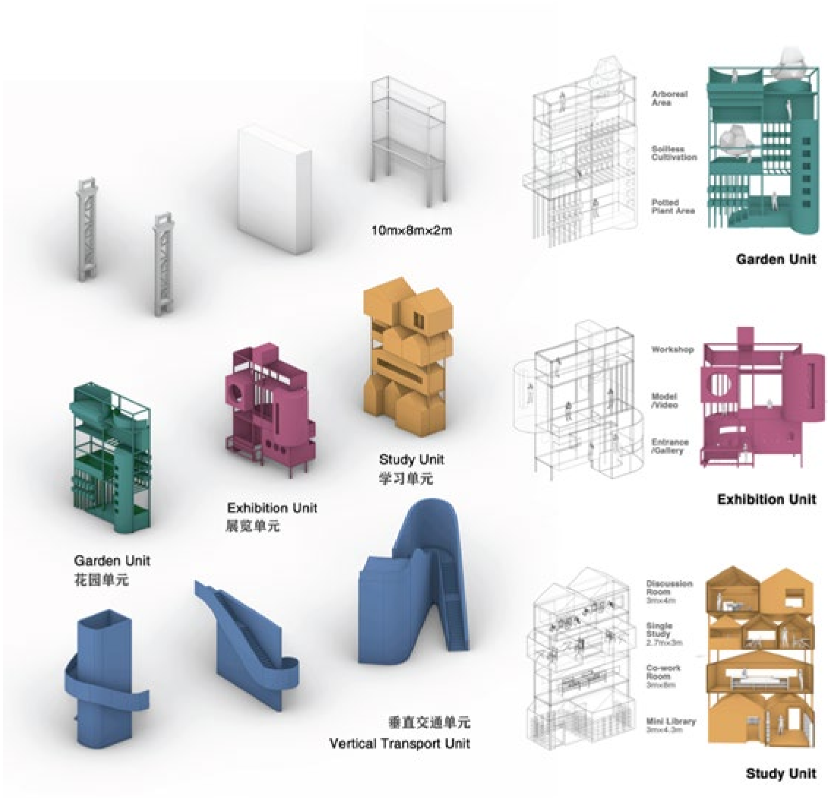


Figure 6.5 Modular and Prefabricated Column-Bay Component Design

Source: Drawn by the author.

In the classification of modular units, the design primarily includes exhibition units, learning units, gardening units, and transportation units, each characterized by its detachable, adjustable, and expandable nature. The exhibition unit is designed to showcase scientific research achievements, industrial heritage content, and temporary exhibitions. Its structural design allows for rapid internal space adjustments to accommodate exhibitions of various scales, utilizing foldable display walls and movable exhibition stands to maximize flexibility. This unit is typically configured in either single-story or double-story designs, ensuring a sense of spatial hierarchy and openness.

The learning unit provides a flexible environment for research and education, including discussion rooms, shared workspaces, and small library corners. These modules generally adopt a single-story layout but can be combined to create multi-level seminar spaces, with adaptable furniture arrangements to accommodate different teaching and communication needs. The gardening unit integrates ecological elements into the industrial factory space through vertical greenery, indoor micro-farms, and air purification systems. This module is designed with a standard height of 4 meters, allowing it to accommodate indoor trees and green walls while enhancing the building's microclimate regulation.

The transportation unit optimizes vertical circulation within the factory, incorporating prefabricated staircases and ramps to improve connectivity between different areas. This unit is typically designed with single or double-story configurations to ensure accessibility while incorporating railings, lighting, and other safety features to enhance visibility and security.

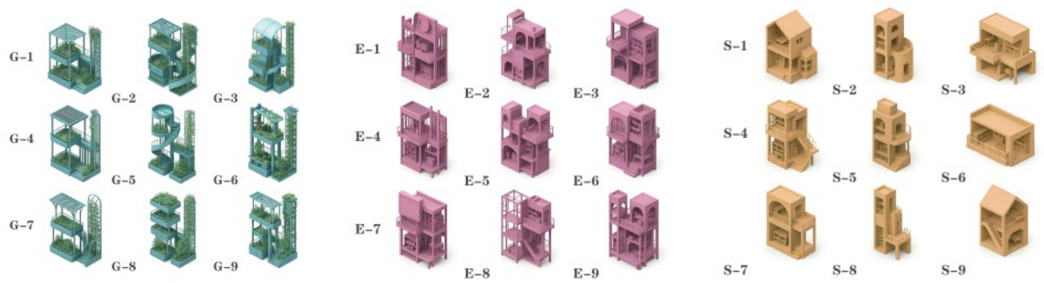


Figure 6.6 Flexible Variation of Infill Components Between Columns

Source: Drawn by the author.

The core characteristics of these modular units are mobility, reconfigurability, and expandability. Unlike traditional fixed spatial layouts, the modular column-bay units can be adjusted, dismantled, or rearranged based on evolving usage needs. To maximize adaptability, the design employs standardized interfaces, ensuring that various functional modules can be quickly assembled or disassembled without requiring extensive modifications to the original building structure. For instance, in the early stages of the project, when the factory is primarily used for academic research and startup incubation, more column-bay spaces may be allocated for office and laboratory modules. As industrial upgrades progress and external exchanges increase, the modular units can be reconfigured to introduce exhibition functions or public activity spaces, enhancing the factory's openness. Additionally, certain functional modules can serve as temporary installations, allowing for flexible relocation and repurposing without disrupting other spaces, thereby accommodating future uncertainties in development.

Regarding material selection, the column-bay units utilize lightweight and high-strength materials such as prefabricated steel structures, renewable timber, and modular concrete units to enable quick assembly and low-impact installation. The connection methods employ bolt assembly and interlocking joints, minimizing structural damage to the existing building during dismantling while ensuring reusability. This strategy enhances spatial adaptability and aligns with sustainable development principles, reducing resource waste and carbon emissions typically associated with industrial heritage renovation.

In terms of spatial organization, the arrangement of modular units is coordinated with the overall functional zoning of the factory. The placement of column-bay units varies according to specific functional needs. For instance, in laboratory and research areas, column-bay spaces are primarily allocated for technology workstations and data processing units to provide an optimal research environment. In public activity zones, exhibition and social modules are strategically incorporated to enhance openness and interaction. In green ecological zones, the introduction of gardening units improves the site's environmental quality while offering a leisure experience for employees and visitors. This strategy ensures a clear spatial logic throughout the building while creating distinct spatial atmospheres in different areas.

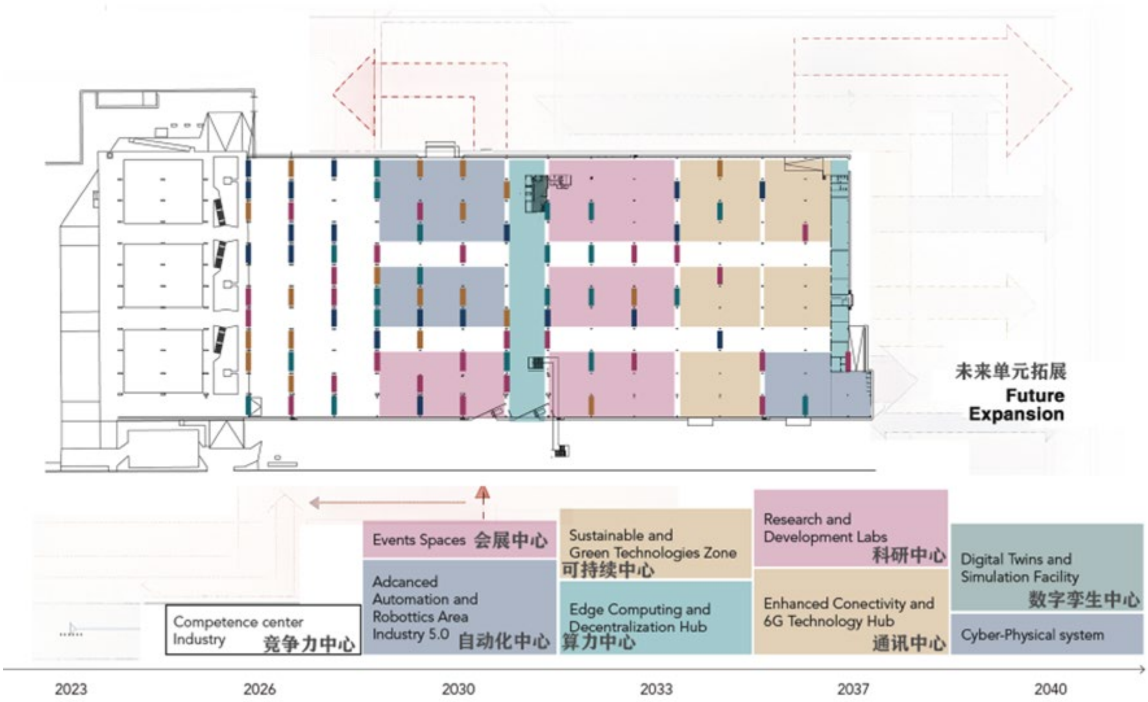


Figure 6.7 Progressive Expansion Model of Components

Source: Drawn by the author.

For phased spatial expansion, the gradual update approach avoids large-scale renovations at once, instead progressing in stages based on existing space conditions and user needs. For example, the initial phase may involve introducing small-scale cultural activities or temporary exhibitions in open spaces to activate the site's atmosphere. Once functional demands stabilize, long-term uses such as commercial, office, and educational facilities can be systematically incorporated. Additionally, the adaptive spatial layout of the renovated factory allows future users to flexibly modify spaces within the original framework, thereby enhancing the durability and versatility of the overall architectural environment.

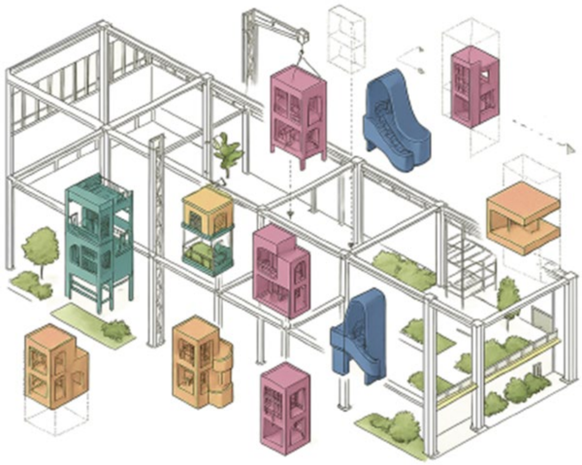


Figure 6.8 Diagram of Prefabricated Infill Unit Insertion Based on Factory Structural Frame

Source: Drawn by the author.

The design of modular prefabricated column-bay units is a significant innovation in the renovation of the Mirafiori factory, maximizing the use of column-bay spaces to accommodate multiple functions while allowing for adjustments and expansions over time. This strategy not only enhances the building's adaptability but also optimizes the functional configuration of its interior spaces, enabling the structure to evolve in response to changes in industrial, research, and urban development needs. The rational scale design ensures flexibility in modular implementation, while the use of prefabricated structures and standardized interfaces significantly improves construction efficiency and sustainability. The introduction of modular units not only optimizes the spatial organization of the factory but also presents a new possibility for adaptive urban design in the future, offering a sustainable and efficient solution for the modernization of industrial heritage.

6.3.2 Enhancing "Structural Compatibility": Shared Cultural Program Planning

In the transformation design of the Mirafiori factory complex, the construction of an open and shared cultural program serves as a crucial strategy for enhancing the public value of space, fostering knowledge exchange, and strengthening community integration. This design proposal centers on spatial accessibility, functional hybridity, and a hierarchical sharing mechanism, establishing a cultural sharing system that integrates openness, flexibility, and layered connectivity through a fully open ground floor, a semi-shared second level, and dynamically linked vertical units.

The ground floor serves as the interface between the factory complex and the city, accommodating multiple functions such as public activities, social interactions, and knowledge dissemination. In the design proposal, most public functions are strategically placed on this level, including exhibition spaces, a conference center, co-working areas, cafés, sports facilities, and various service amenities. The spatial configuration of this level is aimed at maximizing public accessibility, ensuring that different social groups can conveniently engage with the space, thereby creating an efficient hub for social and cultural exchange. Moreover, the openness of the ground floor is not limited to physical accessibility but also extends to temporal and functional flexibility: certain spaces serve researchers and students during the day, while transforming into cultural venues accessible to the public at night, ensuring continuous vibrancy throughout the day.

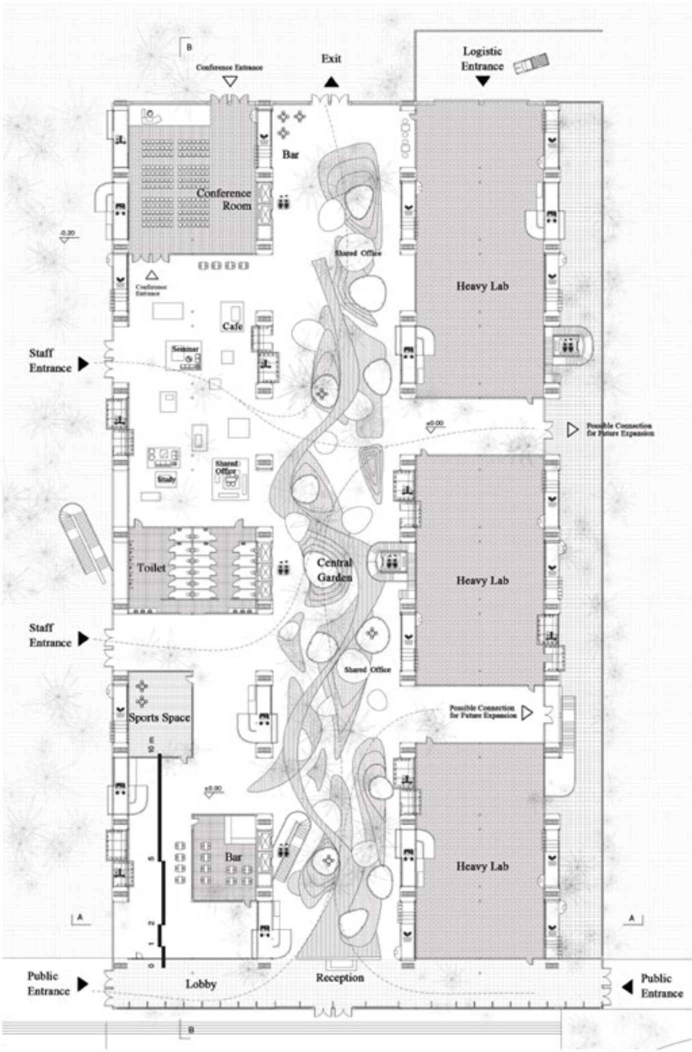


Figure 6.9 Highly Open and Shared Ground Floor and Atrium Space

Source: Drawn by the author.

The second level connects to the existing educational spaces of the Polytechnic University of Turin on the western side of the factory complex, forming a semi-public space with a certain degree of access control. The semi-open nature of this area ensures a balance between academic research and public activities, providing an intermediary space for interaction between academia, industry, and the general public. Specifically, the second level is primarily designated for laboratory expansions, academic exchanges, and research exhibitions, fostering deeper connections between higher education, technological innovation, and urban cultural activities. This spatial configuration not only optimizes the functional distribution of the Mirafiori complex across different user groups but also strengthens the linkage between the university campus and the repurposed industrial site, offering researchers from the Polytechnic University of Turin a more open and integrated practice platform.

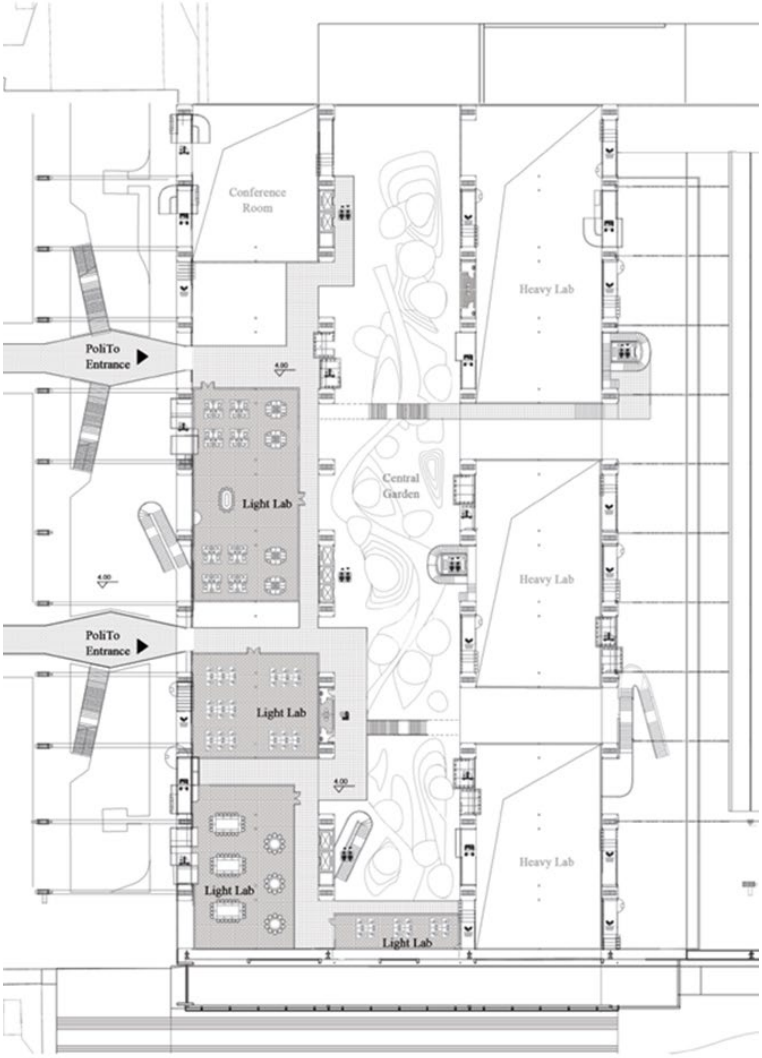


Figure 6.10 Second-Floor Space Coordinated with the Ground Floor and Connecting Existing Buildings

Source: Drawn by the author.

The integration of modular column-bay units further reinforces the vertical sharing mechanism, establishing multidimensional connections between different spatial levels. These modular units are embedded within the original structural grid of the factory, allowing for functional adaptability while preserving architectural integrity. Various types of column-bay units, such as exhibition units, learning units, garden units, and circulation units, not only serve their respective purposes but also facilitate effective inter-level connectivity through staircases, ramps, and open platforms. This vertical sharing system links the open public spaces on the ground floor, the academic exchange spaces on the second level, and the upper-level research laboratories, thereby forming an efficient ecosystem that integrates culture, education, and technology.

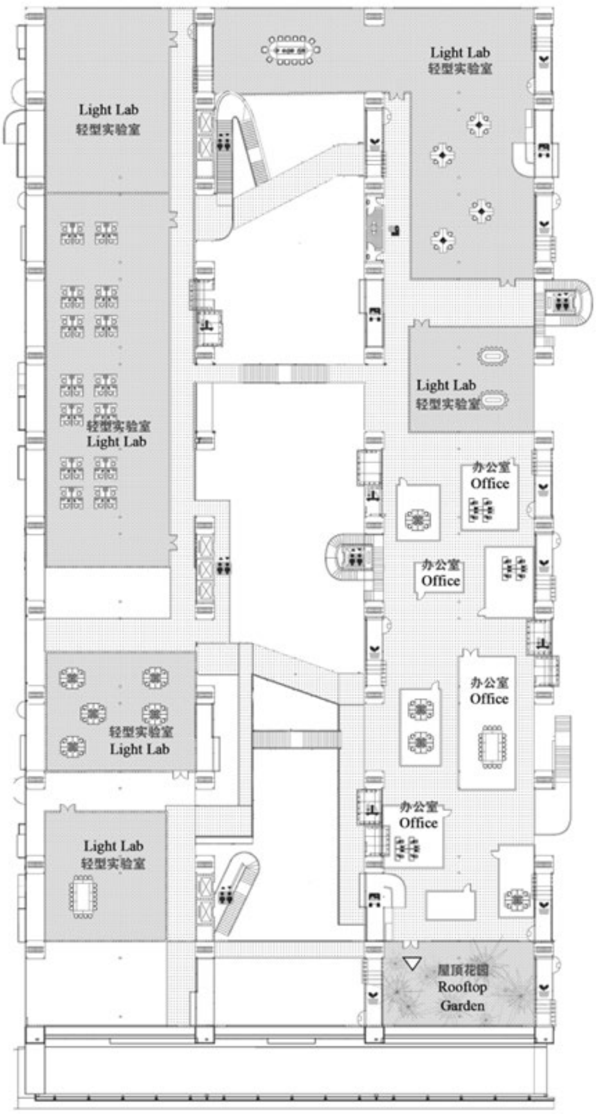


Figure 6.11 Third Floor Plan

Source: Drawn by the author.

Overall, the development of an open and shared cultural program enhances the urban inclusivity of the Mirafiori complex while strengthening the coupling of industrial heritage sites with education, innovation, and cultural activities through spatial accessibility and functional integration. The hierarchical sharing mechanism at the core of this spatial strategy establishes the project as a comprehensive innovation hub that is both accessible to the city and capable of meeting the demands of higher education and industry, providing a sustainable model for the future transformation of industrial heritage sites.

6.3.3 Strengthening "System Circularity": Eco-Sustainable Atrium

The design of the central ecological atrium garden embodies the symbolic transformation of the Mirafiori complex from a deteriorating industrial relic into a revitalized ecological space. This core green area is not merely a physical landscape intervention but a strong response to the ecological restoration of brownfield sites. Once a site of high-intensity industrial production, the land has now been reimagined through ecological strategies, reborn as a vibrant green courtyard. The design philosophy emphasizes environmental sustainability, integrating green infrastructure, optimizing microclimatic conditions, and fostering a harmonious relationship between people and nature, thereby establishing a sustainable model for the future adaptive reuse of industrial heritage.

The atrium garden incorporates multiple ecological sustainability strategies to enhance the overall environmental benefits of the built environment. One of its key features is the rainwater collection system, which includes rooftop and ground-level water harvesting and infiltration devices. This system effectively reduces surface runoff and improves regional water resource management. Additionally, a portion of the collected rainwater is filtered and reused for landscape irrigation, minimizing reliance on municipal water supplies and ensuring the garden's long-term greenery. The spatial configuration of the atrium garden is also optimized to suit the climatic characteristics of the Turin region. Its open structure promotes natural ventilation, creating a cross-ventilation effect during summer months, effectively lowering indoor temperatures and reducing dependence on mechanical cooling systems.

In terms of material selection, the design prioritizes the use of renewable and recycled materials, such as permeable paving, reclaimed wood, and low-carbon concrete, to reduce the project's overall carbon footprint while ensuring compatibility with the historical fabric of the industrial heritage site.

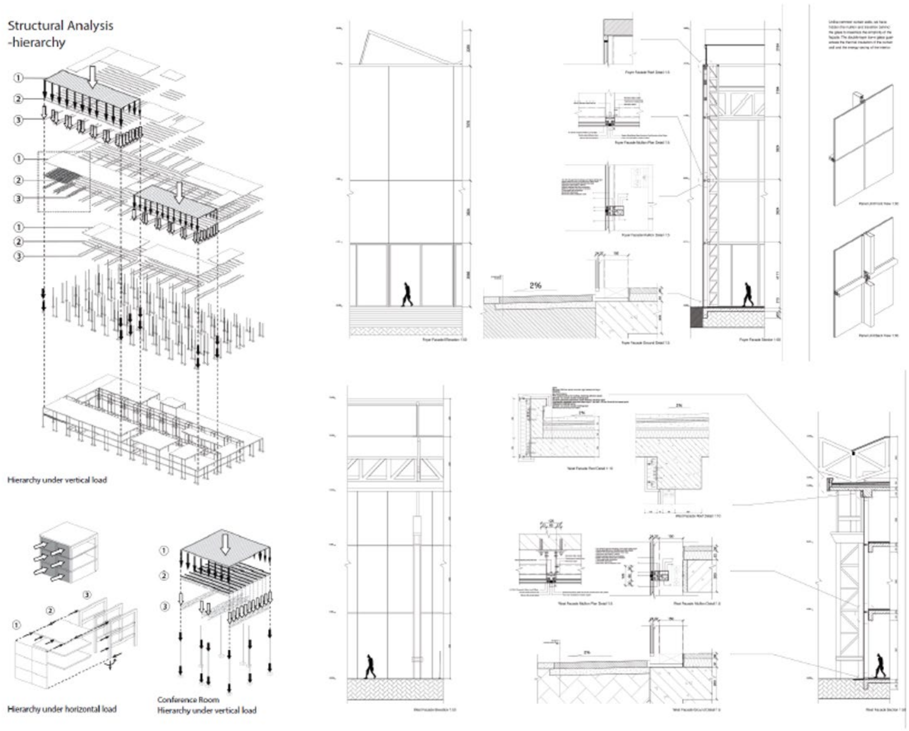


Figure 6.12 Energy-Saving Material System Based on the Original Factory Structure

Source: Drawn by the author.

In the vegetation design, the atrium garden incorporates native plant species adapted to Turin’s local climate, reducing maintenance costs and enhancing ecological stability. The layered planting strategy, combining trees, shrubs, and ground cover plants, not only improves air quality but also helps create a comfortable microclimate within the campus. Additionally, certain plant selections contribute to urban biodiversity by attracting pollinators such as bees and butterflies, as well as providing suitable nesting spaces for small birds, thereby integrating the atrium into the broader ecological network of the city.

Figure 6.13 Transparent and Diverse Internal Axis Perspective

Source: Drawn by the author.

Beyond its ecological function, the atrium garden is also designed as a dynamic space that integrates shared work and social interaction. By strategically arranging co-working units within the garden, the design creates a high-comfort work environment where greenery and workspace blend seamlessly. These co-working spaces are distributed at an optimal density around the garden, with some modular units embedded within the vegetation to form semi-open work areas that provide flexible spaces for working, discussions, and relaxation. This approach not only enhances the spatial diversity of the site but also allows researchers, startup teams, and visitors to engage in their work within a high-quality natural setting, fostering mental agility and stimulating creativity.

Overall, the design of the ecologically sustainable atrium garden is not merely an ecological restoration of the former industrial brownfield but also an exploration of future-oriented sustainable urban spaces. By integrating green infrastructure, adaptive landscape strategies, and shared work environments, the garden not only improves the ecological quality of the site but also establishes an innovative space where human activity and nature coexist harmoniously. This symbiotic approach between ecology and functionality ensures that the transformation of the Mirafiori site goes beyond the mere reuse of physical space, embodying a forward-looking model of ecological innovation.

6.3.4 Reinstating "Sense of Identity": Urban Primary Interface Design

In the redesign of the Mirafiori factory, shaping the urban primary interface is not merely about redefining the architectural image but also about establishing a renewed interaction between the heritage site and the urban environment. Addressing this core issue, the design pursues a dual objective: the continuation of historical memory and the integration of modern innovation. To achieve this, the original factory façade has been meticulously reinterpreted, preserving its emblematic architectural features while introducing new elements of openness and adaptability.

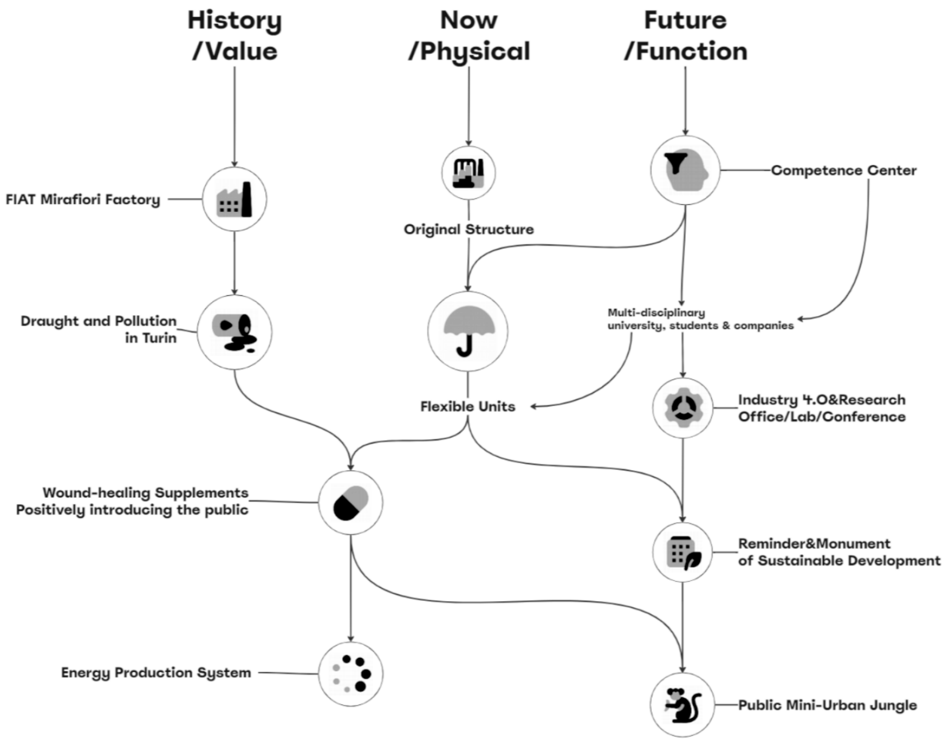


Figure 6.14 Design Strategy Integrating Historical Memory and Modern Innovation

Source: Drawn by the author.

Firstly, in terms of façade strategy, the design introduces a transparency-focused approach to the existing primary interface of the factory, enhancing visual accessibility and transforming it into an open and engaging urban frontage. The original industrial façade is partially preserved, with its modular structural framework meticulously restored to maintain the historical imprint of the building. At the same time, a combination of selective perforations, embedded glass curtain walls, and metal grilles allows the façade to retain its original sense of scale while fostering a stronger visual and spatial connection with the surrounding urban environment. Additionally, a carefully curated nighttime lighting strategy incorporates embedded lighting systems that accentuate the linear characteristics of the structure, ensuring that the building presents a distinctive urban ambiance throughout different times of the day.

Figure 6.15 South Elevation and Section Drawing

Source: Drawn by the author.

Secondly, regarding the arrangement of the main entrance, the design adopts a dual-sided distribution strategy, ensuring smoother circulation and reinforcing the connection with the surrounding urban fabric. Unlike traditional factories that typically rely on a single, enclosed entrance gate, this renovation project employs a multi-point permeability approach, introducing secondary entrances from various directions to allow pedestrian flow from different urban interfaces into the internal space, thereby improving site accessibility. The main entrance space features a stepped plaza that extends outward, creating a transitional gray zone that enhances the site's public attributes while seamlessly integrating with the adjacent road system. Additionally, the design utilizes the elevation difference at the entrance to incorporate a small outdoor theater and exhibition area, offering a diverse range of public activities.

Figure 6.16 Open and Transparent External Entrance Interface

Source: Drawn by the author.

In terms of its relationship with the surrounding roads, the design is centered on the concept of "integration," ensuring a seamless transition between the building and the urban environment. The original factory site was once enclosed by a rigid perimeter wall, which has been partially removed in this renovation to introduce open pedestrian pathways, forming a continuous urban frontage between the building and the street. A linear green belt has been added along the street-facing side, combined with an enhanced pedestrian walkway system, creating a more natural transition and improving walkability for pedestrians. Furthermore, the pedestrian circulation system aligns with the internal visitor pathways, forming a "city promenade" that traverses the entire project. This route allows visitors and citizens to explore the site, immerse themselves in the industrial heritage atmosphere, and experience the seamless transition between different functional zones.

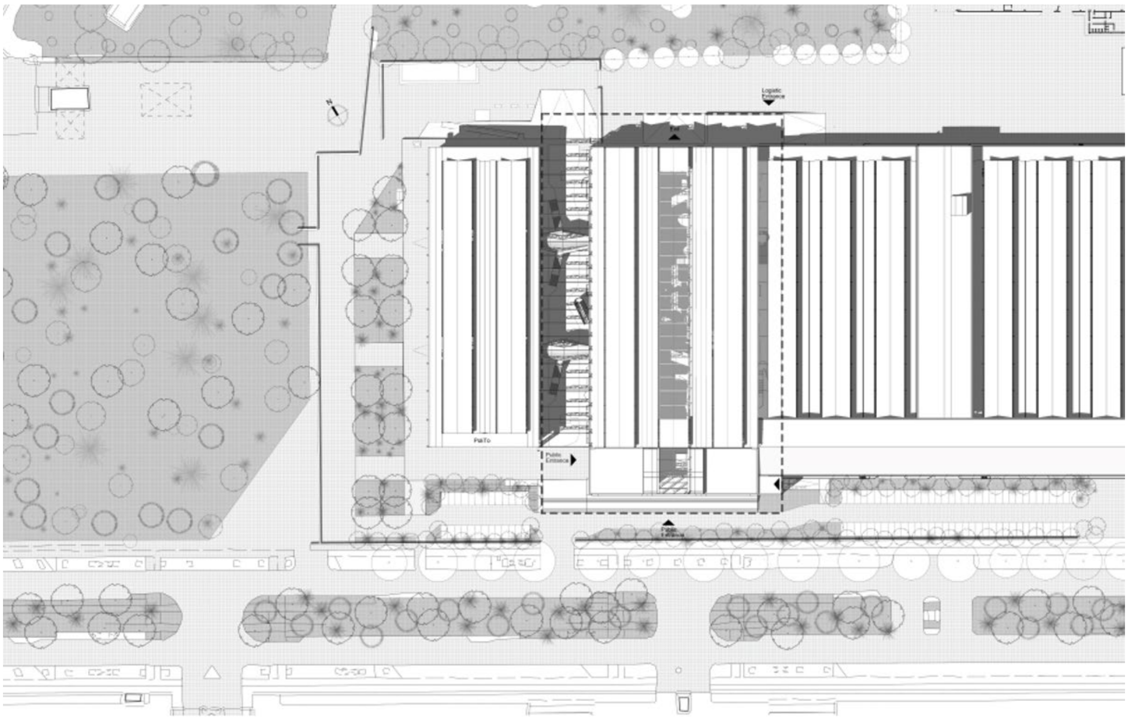


Figure 6.17 Integration of the Project with the Surrounding Urban Spaces

Source: Drawn by the author.

The site design also places particular emphasis on the integration of indoor and outdoor spaces. The central axial courtyard not only serves as a venue for public activities but also acts as a crucial visual and spatial link between interior and exterior environments. To further enhance spatial fluidity, the design incorporates movable shading elements and folding door systems between the courtyard and interior spaces, allowing for flexible adjustments in openness based on varying usage demands. For instance, during large-scale events, the courtyard can function as an extension of the exhibition hall or conference areas, seamlessly connecting indoor and outdoor spaces to provide a more adaptable and dynamic user experience.

Overall, the urban interface design of the Mirafiori Factory retains the historical essence of the industrial heritage while employing modern design strategies to endow it with new urban public significance. The treatment of the façade with transparency enhances the openness of the building, transforming it from a closed production facility into a vibrant hub for cultural and innovation exchange. The integration of the main entrance with the road system improves the urban fabric, ensuring that the heritage site becomes a seamless part of citizens' daily lives. Meanwhile, the holistic approach to indoor-outdoor spatial continuity guarantees a high level of functional adaptability and experiential richness. This comprehensive set of design interventions not only enhances the architectural legibility and urban identity of the site but also offers an exemplary model for industrial heritage revitalization—one that respects historical significance while embracing contemporary innovation.

6.3.5 Developing "Collective Growth Capacity": Spatial Collaborative Governance Model

In the redevelopment of the Mirafiori Factory, the spatial collaborative governance model plays a crucial role, not only ensuring the efficient operation of the site but also shaping interactions and resource-sharing mechanisms among diverse stakeholders. This governance model is structured around a precise spatial-temporal allocation mechanism, allowing different entities to collaborate effectively within the same space while ensuring that the site maintains maximum functionality across different time cycles. Fundamentally, the governance framework operates on two core principles: simultaneous multi-stakeholder collaboration within shared spaces and flexible phased management of different tenants over time. These principles are designed to ensure the long-term sustainability and adaptive resilience of the transformed site.

To optimize the utilization of spatial resources, this project adopts a "functional zoning collaboration + multi-tiered governance" approach, enabling various functional spaces to accommodate different stakeholders simultaneously while fostering mutual development. The key stakeholders include academic institutions, technology enterprises, public agencies, and local community groups, each assuming distinct roles within designated spaces, collectively forming a multi-layered innovation ecosystem.

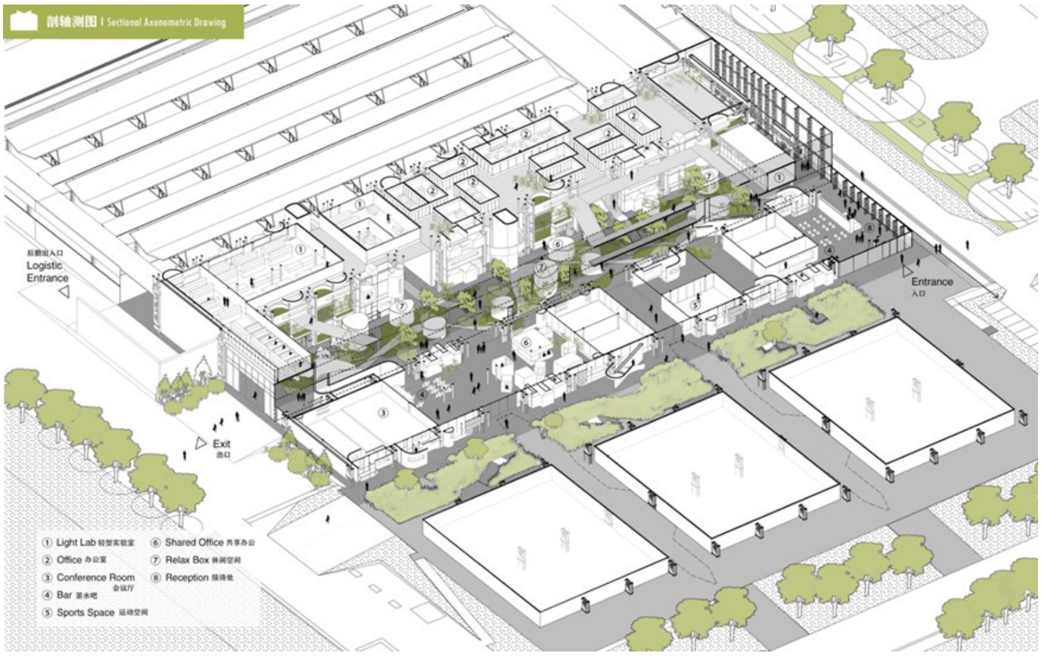


Figure 6.18 The Composite Innovative Ecosystem of the Competence Center

Source: Drawn by the author.

The functional zoning collaboration strategy ensures that spaces are allocated dynamically based on user needs, rather than being rigidly designated for a single purpose. For instance, research laboratories can be shared between university research groups and industry partners, while flexible office spaces can be allocated to startups during weekdays and repurposed for community co-working initiatives on weekends. Likewise, public exhibition areas can serve both as educational forums for academic institutions and as networking hubs for entrepreneurs, maximizing cross-sector interaction.

The multi-tiered governance framework establishes clear operational and decision-making responsibilities at different levels. A core governance body, comprising representatives from universities, enterprises, local government, and cultural organizations, oversees long-term strategic planning, ensuring alignment between industrial innovation, academic research, and public engagement. Meanwhile, sector-specific committees manage operational aspects within their respective domains, such as research, entrepreneurship incubation, cultural programming, and environmental sustainability. At the grassroots level, a community engagement platform allows local residents and independent creators to contribute to programming decisions, ensuring that public interests are embedded within the site's governance structure.

This governance model also incorporates a flexible temporal framework to accommodate evolving stakeholder needs. Spaces within the Mirafiori Factory are designed for time-sharing models, allowing them to serve different purposes across various timeframes. For example, meeting rooms and lecture halls function as corporate training facilities during business hours and transform into evening educational workshops for the local community. Similarly, outdoor spaces designated for open-air markets on weekends can serve as green recreational areas on weekdays. This adaptable scheduling mechanism not only maximizes space utilization but also enhances inclusivity by making the site accessible to a broader range of users.

By integrating spatial and governance adaptability, the redevelopment of Mirafiori Factory fosters a collaborative, multi-stakeholder innovation hub, ensuring long-term economic, social, and environmental sustainability. The flexible governance structure facilitates continuous engagement from both institutional and grassroots actors, ensuring that the site remains dynamic, relevant, and resilient to future changes. This spatial collaborative governance model thus represents a forward-thinking approach to industrial heritage transformation, setting a precedent for adaptive reuse strategies that balance historical preservation with contemporary urban innovation.

First, the experimental and office areas, including the lightweight laboratories and co-working spaces, are shared primarily by research teams from Politecnico di Torino, high-tech enterprises, and startup companies. These spaces operate under a shared office model, with infrastructure support provided by the university's research center and daily management overseen by the site’s operational team. This ensures deep integration between technological enterprises and academic institutions. Additionally, regular industry matchmaking events are organized, enabling businesses to interact directly with research teams, thereby forming a closed-loop collaboration between scientific research and market demand.

Second, the cultural and exhibition spaces, which include the multifunctional conference center, exhibition halls, and artistic installation areas, are jointly managed by the government’s cultural departments, nonprofit organizations, and the city’s creative industries. These spaces follow an open-access operational model, with initial financial support from the government, daily programming handled by cultural institutions, and public accessibility ensured to encourage citizen participation. Furthermore, technology companies and universities can utilize these spaces to host product launches, exhibitions, and forums, increasing public awareness of cutting-edge technology and urban innovation.

Figure 6.19 Interlaced Arrangement of Laboratory, Office, and Exhibition Spaces

Source: Drawn by the author.

The central shared garden and recreational public spaces are co-governed by community groups, startup businesses, and local residents, forming an inclusive social space. These areas serve not only researchers and corporate employees but are also open to the general public, creating a diverse, shared living environment. The governance model encourages community organizations to initiate events regularly, while businesses can sponsor or co-host activities to foster a mutually beneficial relationship. For example, health technology companies may organize exhibitions on sustainable design or host environmental-themed lectures, while local residents can participate in green community-building initiatives within the park.

Additionally, the redevelopment of the Mirafiori Factory incorporates modular prefabricated units, allowing for highly flexible spatial configurations. This adaptability necessitates an operational model capable of accommodating the evolving demands of different industries and market conditions. Consequently, the governance model places particular emphasis on peak and off-peak space utilization strategies, dynamically adjusting tenant occupancy over different time periods to achieve optimal resource allocation.

Figure 6.20 The Peak and Valley Utilization Strategy of Space

Source: Drawn by the author.

First, in short-term management on a daily or weekly basis, the project adopts a time-sharing strategy that matches different user needs at different times of the day. For example, the conference center serves university seminars and corporate business meetings during the day, while in the evening, it transforms into a venue for public cultural events such as open lectures and film screenings. Similarly, laboratories and co-working spaces are primarily used by research teams and startups during the day, while at night or on weekends, they can be made available to freelancers or short-term innovation teams, thereby increasing space utilization efficiency.

Second, in mid-term management on a quarterly or yearly basis, a flexible occupancy mechanism is implemented, allowing the composition of tenant institutions to be adjusted in response to industry trends and evolving demands. For instance, the startup incubation area can be dynamically adjusted based on the growth stages of incubated enterprises. Newly established businesses can apply for short-term residency, while growing enterprises may secure long-term leases. At the same time, the government and universities can periodically reallocate public resources, such as converting part of the office space into an entrepreneurship training center to meet specific market needs at different times.

Finally, in long-term management on a five-to-ten-year cycle, the site's operational team will make systematic spatial adjustments based on urban development strategies and technological industry evolution trends. For example, the current project focuses on 6G communications and green technologies, but as industries evolve, certain spaces may need to be reconfigured for smart manufacturing or artificial intelligence laboratories. To ensure the adaptability of the space, a periodic evaluation mechanism will be established, allowing the government, research institutions, and industry alliances to collaboratively determine future spatial adjustments, ensuring the long-term sustainability of the project.

To effectively implement this governance model, a multi-level collaborative management system has been established, where government and universities provide policy support, invest in infrastructure, and oversee overall spatial planning. Enterprises and startups drive technological innovation and industrial applications while also assisting in the operation and maintenance of shared office and laboratory facilities. Cultural and community organizations manage public activity spaces, fostering social inclusivity and cultural vibrancy. An independent operating entity serves as a neutral management body, coordinating the needs of all stakeholders, overseeing daily operations, and conducting periodic data analysis to optimize spatial usage.

Through the implementation of this collaborative spatial governance model, the transformation of Mirafiori Factory not only enables synergy between industrial innovation and academic research but also fosters cultural exchange and community engagement at the urban level. This model fully considers the needs of diverse stakeholders and integrates a dynamic time-based management strategy, allowing the space to adapt to market and societal changes over different time cycles. Ultimately, this governance framework serves as an effective demonstration of industrial heritage reuse in Turin while offering a replicable strategy for similar urban regeneration projects worldwide.

6.4 Design Summary

The renovation design of the Mirafiori Factory is based on the results of a systemic factor synergy evaluation and is structured around five core transformation strategies to ensure the scientific and systematic nature of the transition plan. This study integrates social network analysis and expert scoring methods to construct an industrial heritage transformation factor system, identifying the key elements influencing the site's redevelopment, including spatial adaptability, ecological sustainability, social inclusivity, industrial synergy, and multi-stakeholder governance. These evaluation results provide a solid theoretical foundation for formulating design strategies and ensure that each factor is effectively reflected in the transformation plan.

The design process follows a data-driven decision-making approach, where the preliminary synergy assessment reveals the interactions between spatial, environmental, economic, and social dimensions within the Mirafiori Factory and identifies highly correlated and high-impact key factors. These findings offer precise direction for functional layout, architectural renovation, and environmental optimization decisions. Rather than simply applying five independent strategies, the design integrates them based on their synergistic relationships, forming a comprehensive application of five core strategies: mixed-use functionality and spatial diversity, culture-driven industry regeneration, green infrastructure integration, fusion of historical memory with modern innovation, and multi-level collaborative governance. This systematic approach ensures functional transformation, social integration, economic growth, and environmental sustainability, providing a feasible operational pathway for industrial heritage revitalization.

This study not only constructs a theoretical framework for synergistic factor evaluation at an academic level but also validates it through practical application in the Mirafiori Factory renovation design. The theoretical framework offers scientific guidance for the design, while the renovation plan’s feedback analysis further reinforces the synergistic interactions between key factors. The innovation of this research lies in its tight integration of synergy evaluation with design strategies, presenting a holistic approach to industrial heritage transformation.

7 Research Conclusion

7.1 Research Summary

This study focuses on the synergistic evaluation and design strategies for industrial heritage transformation, with a specific focus on case studies in Turin, Italy. By combining quantitative and qualitative analyses, the research has led to the following key conclusions:

First, from a theoretical and methodological perspective, this study establishes an integrated evaluation framework that incorporates multi-dimensional factors affecting industrial heritage transformation and introduces social network analysis (SNA) to map the relationships and interactions between these factors. The framework is grounded in synergetics theory and integrates international heritage conservation guidelines and sustainability indicators, ensuring a comprehensive and scientific assessment approach. By applying SNA, the study takes a holistic view of the industrial heritage transformation process, capturing complex interdependencies that traditional single-indicator assessments fail to reveal. Empirical analysis of the three Turin case studies confirms that this synergistic evaluation method effectively identifies the key success factors and transformation models, contributing to the methodological advancement of industrial heritage research. Therefore, this study’s methodological contribution lies in the construction of a combined evaluation index system and network analysis tool, offering a new perspective for similar research endeavors.

Second, based on empirical studies in Turin, this research unveils the synergistic mechanisms and patterns of industrial heritage transformation. A comparative analysis of Dora Park, OGR Innovation Hub, and the Lingotto Complex demonstrates that successful industrial heritage projects tend to exhibit a multi-factor synergy effect, where economic, social, cultural, and environmental dimensions do not evolve in isolation but rather interact and improve simultaneously throughout the transformation process. Different project types display varying synergy focal points—eco-park models emphasize environmental-social synergy, cultural-creative models focus on cultural-economic synergy, and mixed-use redevelopment models are driven by an economic-cultural dual synergy. However, “cultural and social” factors consistently play a central role in all case studies, acting as a bridge between economic and environmental dimensions. This finding underscores that successful industrial heritage transformation must integrate cultural heritage and community engagement alongside physical redevelopment to achieve a comprehensive and sustainable outcome.

Additionally, network analysis highlights key transformation themes, including multi-level governance, cultural innovation, environmental improvement, functional hybridity, and historical continuity. The OGR project, which exhibits the highest network density, excels in all these aspects, leading to a qualitative leap in transformation success. Conversely, neglecting any of these factors can significantly undermine the transformation outcome. This finding validates the theoretical argument that industrial heritage transformation requires a systematic and synergistic approach—improvements in a single dimension are insufficient to sustain a complex transformation, and only through multi-dimensional synergy can transformation be both deep and broad.

Third, on a practical level, this study proposes five key design strategies for industrial heritage transformation, based on the synergy evaluation findings: mixed-use functional layout, culture-driven industry regeneration, green infrastructure integration, historical-innovation fusion, and multi-level collaborative governance. Each strategy directly addresses specific weaknesses or key synergy factors identified in the evaluation, ensuring strong relevance and practical applicability. For instance, to counteract governance deficiencies, the co-governance platform strategy is proposed; to enhance cultural vitality, the cultural hub strategy is introduced; to overcome functional rigidity, the hybrid-use strategy is implemented; to mitigate environmental risks, the green restoration strategy is prioritized; and to preserve site identity, the historical integration strategy is emphasized. The systematic combination of these strategies allows industrial heritage projects to optimize the entire transformation process—from planning and spatial design to operational management—thus maximizing heritage value. The insights drawn from the Turin case studies have been distilled and refined into universally applicable principles, providing a valuable reference for industrial cities worldwide. Consequently, the study’s practical contribution lies in bridging the gap between evaluation and intervention strategies, forming a comprehensive, actionable framework for guiding industrial heritage transformation.

Finally, by using Turin as a case study, this research provides insights for industrial heritage transformation in China and other regions. Turin’s successful transformation demonstrates that old industrial cities can achieve revival through strategic planning and coordinated development. The key is to balance industrial renewal with heritage conservation, align public aspirations with urban development goals, and leverage innovation to turn challenges into opportunities. As China undergoes industrial restructuring and urban regeneration, a vast number of industrial heritage sites require adaptive reuse, making Turin's experience and this study's strategies highly relevant. For instance, Chinese cities could explore cultural-industrial synergy models, corridor-based master planning, and increased public-private collaboration. Ultimately, industrial heritage is more than just physical structures—it is a historical asset that, when subjected to scientific evaluation and collaborative design, can become a catalyst for sustainable urban development.

7.2 Research Limitations and Future Prospects

Although this study constructs an evaluation framework for industrial heritage transformation based on a synergistic assessment method for factor systems and proposes systematic design strategies, certain limitations remain. Throughout the research process, aspects such as the applicability of theoretical frameworks, the completeness of data collection, and the feasibility of proposed strategies still have room for further refinement.

First, in terms of evaluation data, the study primarily relies on expert questionnaire-based subjective judgments, which, despite statistical processing, may still introduce subjective biases. The limited number of experts constrains the representativeness of the data. Due to time and resource constraints, this study mainly engaged experts from specific domains, while broader participation from key stakeholders, such as government policymakers, community residents, and business representatives, remains insufficient. Future research could expand multi-stakeholder engagement mechanisms by conducting larger-scale surveys, interviews, or focus group discussions to enhance the diversity of data sources and improve the generalizability of assessment results. Additionally, integrating objective data—such as pre- and post-redevelopment economic indicators, environmental monitoring data, and social survey results—could further validate the findings, improving their objectivity and credibility.

Second, the social network analysis (SNA) method used in this study constructs networks based on binary (0-1) relationships, without differentiating the strength of synergies between factors. Future research could introduce weighted network analysis, using continuous values to represent varying degrees of synergy. Applying advanced network algorithms, such as centrality analysis and community detection, could provide deeper insights into the interactions between key transformation elements.

Furthermore, this study focuses on three case studies in Turin, limiting the sample size. To enhance the generalizability of conclusions, future research could apply the evaluation method to more cities and projects for comparative cross-sectional analysis, testing the adaptability of the proposed strategies under different contexts. Industrial heritage transformation is a complex process influenced by policy frameworks, market dynamics, social demands, and spatial adaptability, where the relationships between transformation factors may fluctuate over time due to external environmental changes. However, this study is based on static data analysis, which does not fully capture the dynamic evolution of synergy mechanisms. Future research could incorporate longitudinal tracking studies or dynamic simulation models to explore the temporal evolution of synergy interactions in industrial heritage transformation.

Looking ahead, industrial heritage transformation has become a key topic in global urban regeneration. Achieving a balance between heritage preservation, functional innovation, social participation, and environmental sustainability will be a central challenge in industrial heritage research. With the advancement of digital technologies, artificial intelligence, and urban big data analytics, future studies could explore how to leverage machine learning, GIS spatial analysis, and intelligent optimization algorithms to enhance the accuracy of transformation assessments and optimize design decision-making processes.

Moreover, industrial heritage sites vary significantly across different regions due to cultural backgrounds, socio-economic conditions, and policy support systems. Future research could strengthen comparative international studies, distilling adaptive industrial heritage transformation models that are applicable across different contexts to develop a more systematic and globally relevant theoretical framework.

Overall, this study represents an exploratory effort, providing a novel methodological attempt for industrial heritage evaluation and extracting practical transformation strategies. However, there is still a long way to go before these findings can be fully integrated into large-scale practical applications. More empirical studies and real-world validations are needed to enrich and refine the proposed approaches. Hopefully, this research will serve as a catalyst for further discussions and innovations in synergistic industrial heritage transformation. Only by bringing together interdisciplinary perspectives and practical insights can we effectively protect and revitalize industrial heritage, allowing the glory of past industrial eras to shine in the new age of sustainable urban development.

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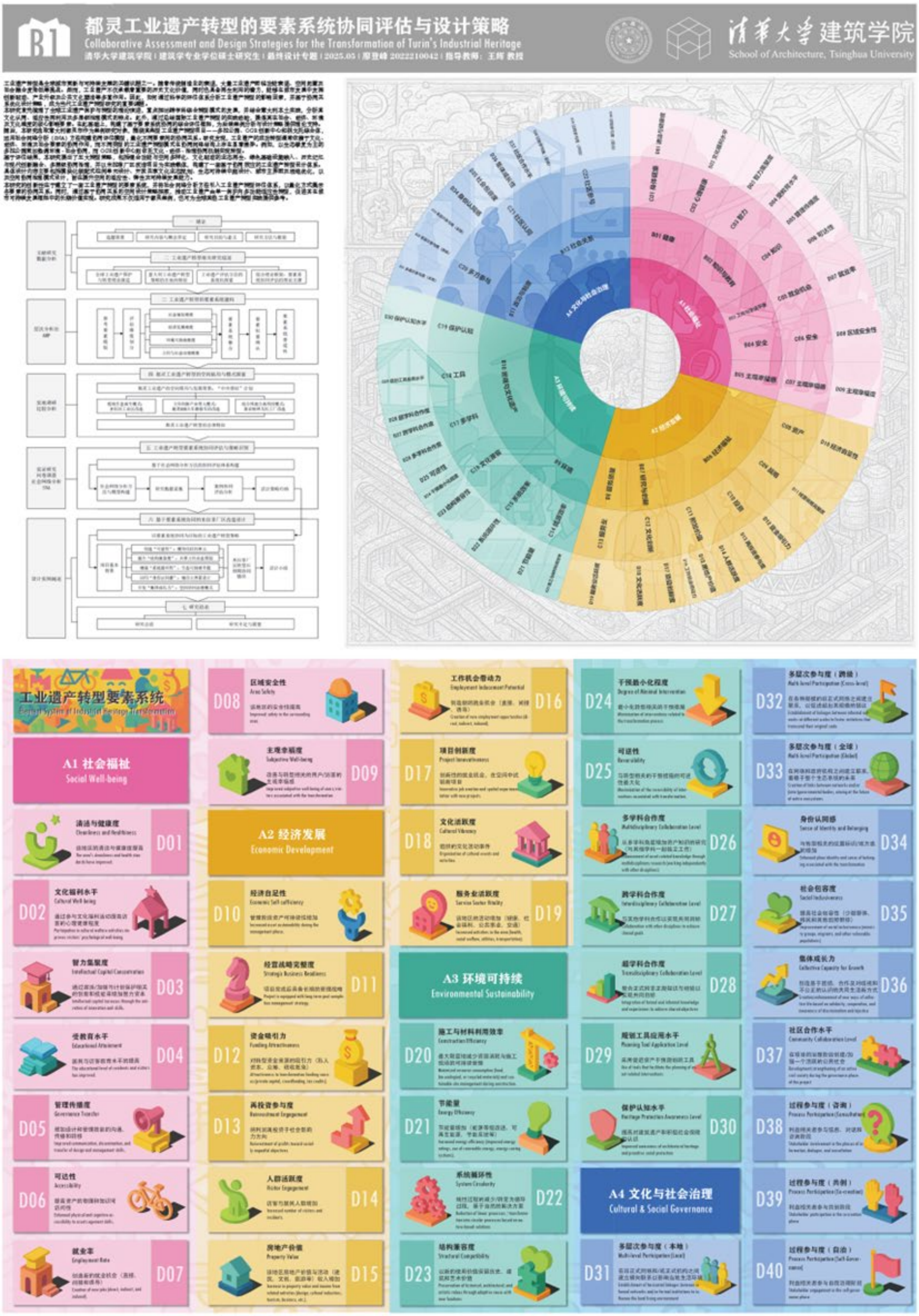
Appendix A　Collaborative Assessment Scale for Industrial Heritage Transformation

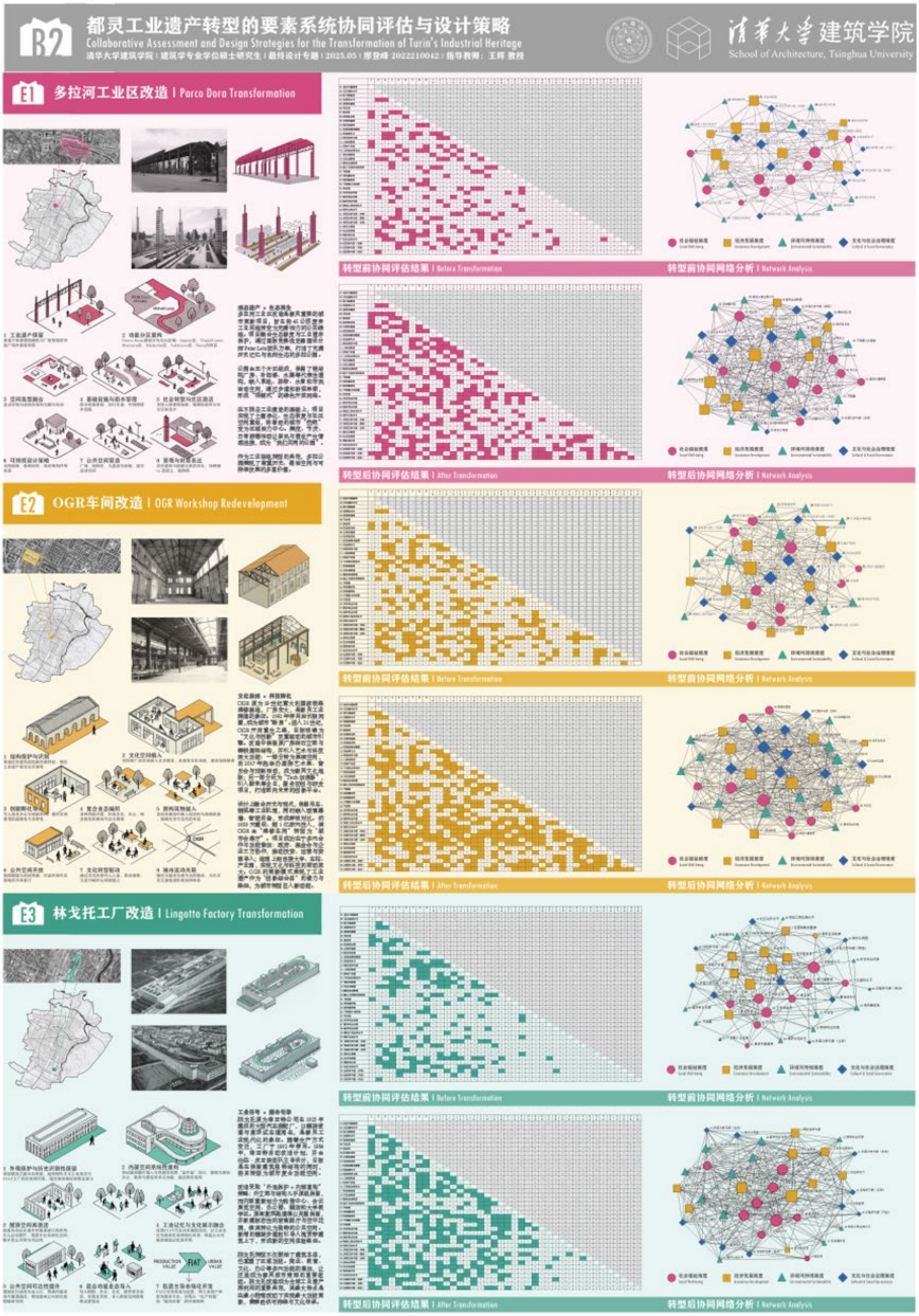
尊敬的专家:
您好，非常感谢您参与本次专家打分。本研究旨在构建一个多维协同的工业遗产转型评估体系，以对不同维度中，工业遗产代表项目各指标之间的协同程度进行评估。在以下矩形白色框中，如果两个指标存在明显的协同性，请标记数字"1"，反之则为"0"。请您根据您所了解的真实情况，尽可能准确地回答问题。
您的评价将为我提供宝贵的研究数据，帮助优化工业遗产的转型利用方法和策略。在此向您承诺，所有数据都将保密并只用于学术研究。
感谢您百忙之中填写评价表，向您致以万分的感谢!
Dear Expert:
Hello, thank you very much for participating in this expert scoring session. This research aims to construct a multidimensional collaborative assessment system for the transformation of industrial heritage, in order to assess the degree of synergy among various indicators of industrial heritage projects across different dimensions. In the rectangular white box below, if there is a clear synergy between two indicators, please mark with the number "1"; otherwise, mark with "0". Please answer the questions as accurately as possible based on your understanding of the actual situation.
Your evaluation will provide valuable research data to help optimize methods and strategies for the transformation and utilization of industrial heritage. I assure you that all data will be kept confidential and used solely for academic research.
Thank you very much for taking the time to fill out the evaluation form. I extend my deepest gratitude to you!

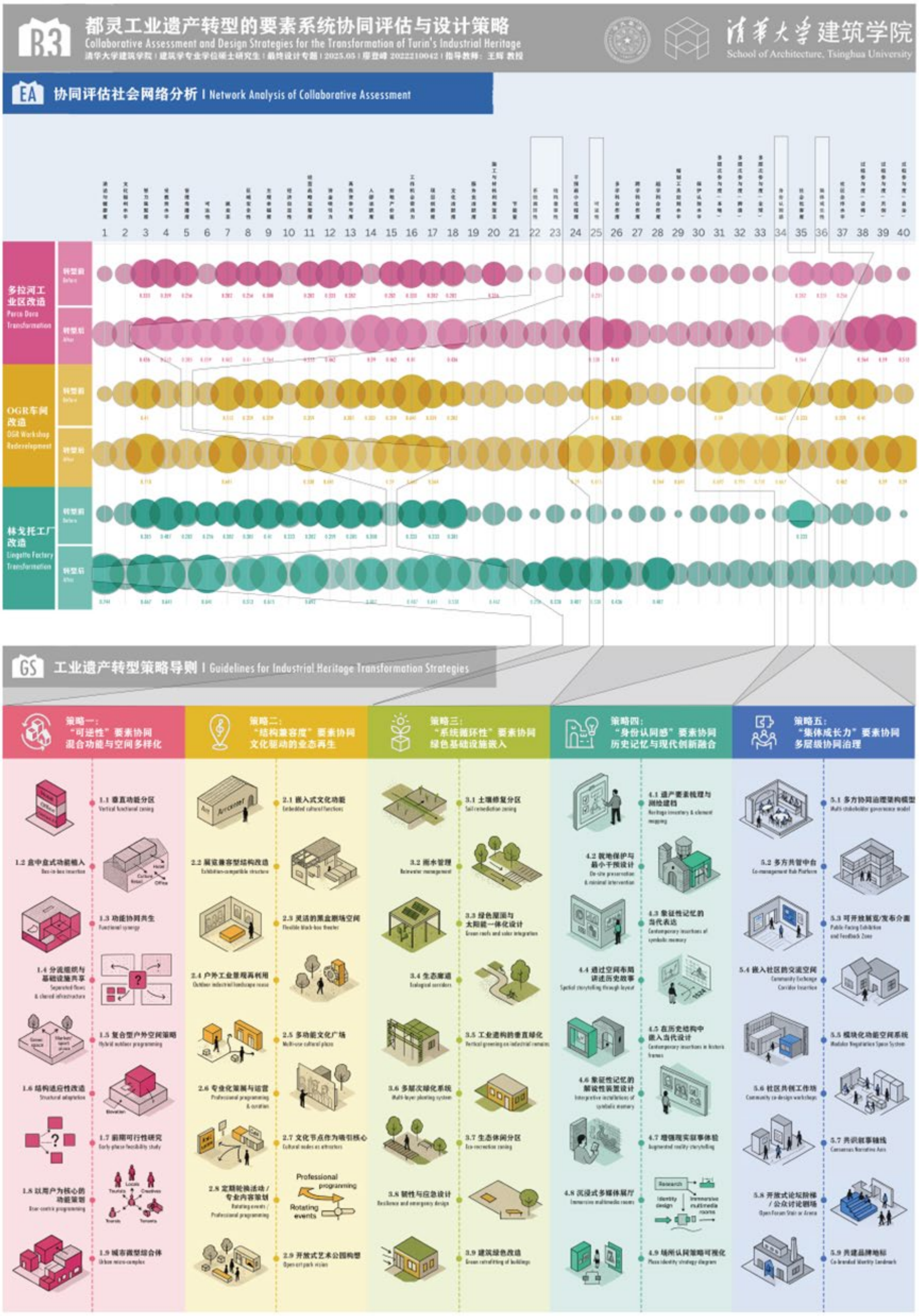
都灵工业遗产转型要素系统协同评估表
Collaborative Evaluation Table of Elemental System in the Transformation of Turin's Industrial Heritage

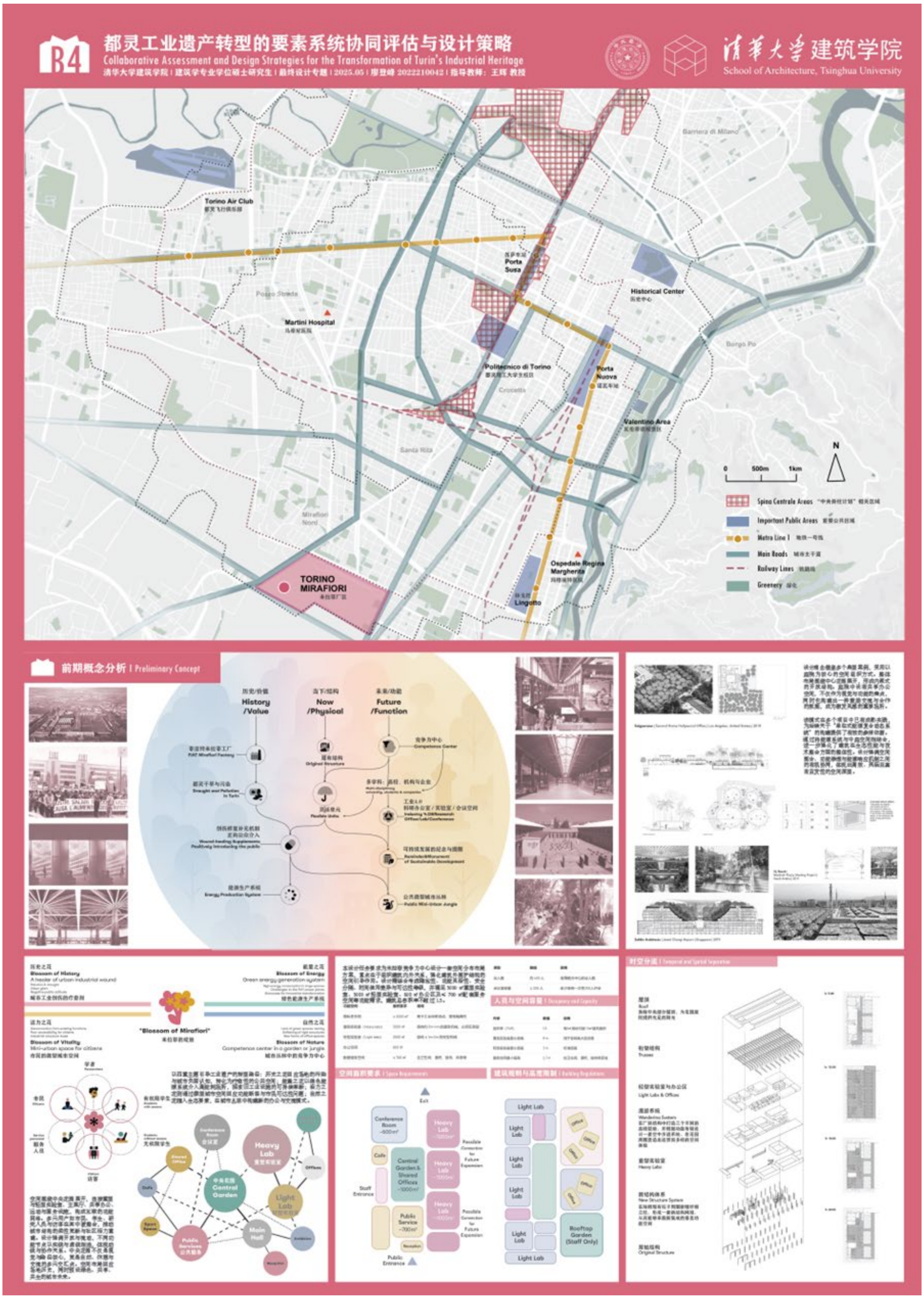
指标	D1 清洁与健康度	D2 文化福利水平	D3 智力集聚度	D4 受教育水平	D5 管理传播度	D6 可达性	D7 就业率	D8 区域安全性	D9 主观幸福度	D10 经济自足性	D11 经营战略完整度	D12 资金吸引力	D13 再投资参与度	D14 人群活跃度	D15 房地产价值	D16 工作机会带动力	D17 项目创新度	D18 文化活跃度	D19 服务业活跃度	D20 施工与材料利用效率	D21 节能量	D22 系统循环性	D23 结构兼容性	D24 干预最小化程度	D25 可逆性	D26 多学科合作度	D27 跨学科合作度	D28 超学科合作度	D29 规划工具应用水平	D30 保护认知水平	D31 多层次参与度（本地）	D32 多层次参与度（跨级）	D33 多层次参与度（全球）	D34 身份认同感	D35 社会包容度	D36 集体成长性	D37 社区合作水平	D38 过程参与度（咨询）	D39 过程参与度（共创）	D40 过程参与度（自治）
D1 清洁与健康度 Cleanliness and Health Level	/																																							
D2 文化福利水平 Cultural Welfare Level	0	/																																						
D3 智力集聚度 Intellectual Concentration Degree	0	0	/																																					
D4 受教育水平 Education Reception Level	0	0	0	/																																				
D5 管理传播度 Management Dissemination Degree	0	0	0	0	/																																			
D6 可达性 Accessibility	0	0	0	0	0	/																																		
D7 就业率 Employment Rate	0	0	0	0	0	0	/																																	
D8 区域安全性 Regional Safety	0	0	0	0	0	0	0	/																																
D9 主观幸福度 Subjective Happiness	0	0	0	0	0	0	0	0	/																															
D10 经济自足性 Economic Self-Sufficiency	0	0	0	0	0	0	0	0	0	/																														
D11 经营战略完整度 Completeness of Economic Strategy	0	0	0	0	0	0	0	0	0	0	/																													
D12 资金吸引力 Capital Attraction Degree	0	0	0	0	0	0	0	0	0	0	0	/																												
D13 再投资参与度 Reinvestment Degree	0	0	0	0	0	0	0	0	0	0	0	0	/																											
D14 人群活跃度 Population Vitality	0	0	0	0	0	0	0	0	0	0	0	0	0	/																										
D15 房地产价值 Property Value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																									
D16 工作机会带动力 Job Contribution to Momentum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																								
D17 项目创新度 Project Innovation Level	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																							
D18 文化活跃度 Cultural Livelihood Level	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																						
D19 服务业活跃度 Service Activity Level	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																					
D20 施工与材料利用效率 Efficiency of Construction and Materials	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																				
D21 节能量 Energy Efficiency	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																			
D22 系统循环性 System Circulation Degree	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																		
D23 结构兼容性 Functional Compatibility	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																	
D24 干预最小化程度 Minimization of Intervention	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/																
D25 可逆性 Reversibility	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/															
D26 多学科合作度 Multidisciplinary Collaboration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/														
D27 跨学科合作度 Interdisciplinary Collaboration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/													
D28 超学科合作度 Super-disciplinary Collaboration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/												
D29 规划工具应用水平 Level of Planning Tool Application	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/											
D30 保护认知水平 Protection Awareness Level	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/										
D31 多层次参与度（本地） Multi-layer Participation (Local)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/									
D32 多层次参与度（跨级） Multi-layer Participation (Regional)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/								
D33 多层次参与度（全球） Multi-layer Participation (Global)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/							
D34 身份认同感 Social Identity Consistency	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/						
D35 社会包容度 Social Inclusiveness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/					
D36 集体成长性 Community Cohesion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/				
D37 社区合作水平 Community Cooperation Level	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/			
D38 过程参与度（咨询） Process Participation (Consultation)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/		
D39 过程参与度（共创） Process Participation (Co-creation)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/	
D40 过程参与度（自治） Process Participation (Autonomy)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	/

Appendix B　Design Drawings




B2
都灵工业遗产转型的要素系统协同评估与设计策略
Collaborative Assessment and Design Strategies for the Transformation of Turin's Industrial Heritage
清華大學建筑学院
School of Architecture, Tsinghua University
E1 多拉河工业区改造 | Parco Dora Transformation
转型前协同评估结果 | Before Transformation
转型前协同网络分析 | Network Analysis
转型后协同评估结果 | After Transformation
转型后协同网络分析 | Network Analysis
E2 OGR车间改造 | OGR Workshop Redevelopment
转型前协同评估结果 | Before Transformation
转型前协同网络分析 | Network Analysis
转型后协同评估结果 | After Transformation
转型后协同网络分析 | Network Analysis
E3 林戈托工厂改造 | Lingotto Factory Transformation
转型前协同评估结果 | Before Transformation
转型前协同网络分析 | Network Analysis
转型后协同评估结果 | After Transformation
转型后协同网络分析 | Network Analysis


B3
都灵工业遗产转型的要素系统协同评估与设计策略
Collaborative Assessment and Design Strategies for the Transformation of Turin's Industrial Heritage
清华大学建筑学院 | 建筑学专业学位硕士研究生 | 最终设计专题 | 2025.05 | 廖登峰 2022210042 | 指导教师：王辉 教授
清华大学建筑学院
School of Architecture, Tsinghua University
EA 协同评估社会网络分析 | Network Analysis of Collaborative Assessment
多拉河工业区改造
Parco Dora Transformation
OGR车间改造
OGR Workshop Redevelopment
林戈托工厂改造
Lingotto Factory Transformation
GS 工业遗产转型策略导则 | Guidelines for Industrial Heritage Transformation Strategies
策略一："可逆性"要素协同 混合功能与空间多样化
策略二："结构兼容度"要素协同 文化驱动的业态再生
策略三："系统循环性"要素协同 绿色基础设施嵌入
策略四："身份认同感"要素协同 历史记忆与现代创新融合
策略五："集体成长力"要素协同 多层级协同治理
1.1 垂直功能分区 Vertical functional zoning
2.1 嵌入式文化功能 Embedded cultural functions
3.1 土壤修复分区 Soil remediation zoning
4.1 遗产要素梳理与测绘建档
5.1 多方协同治理架构模型


B4
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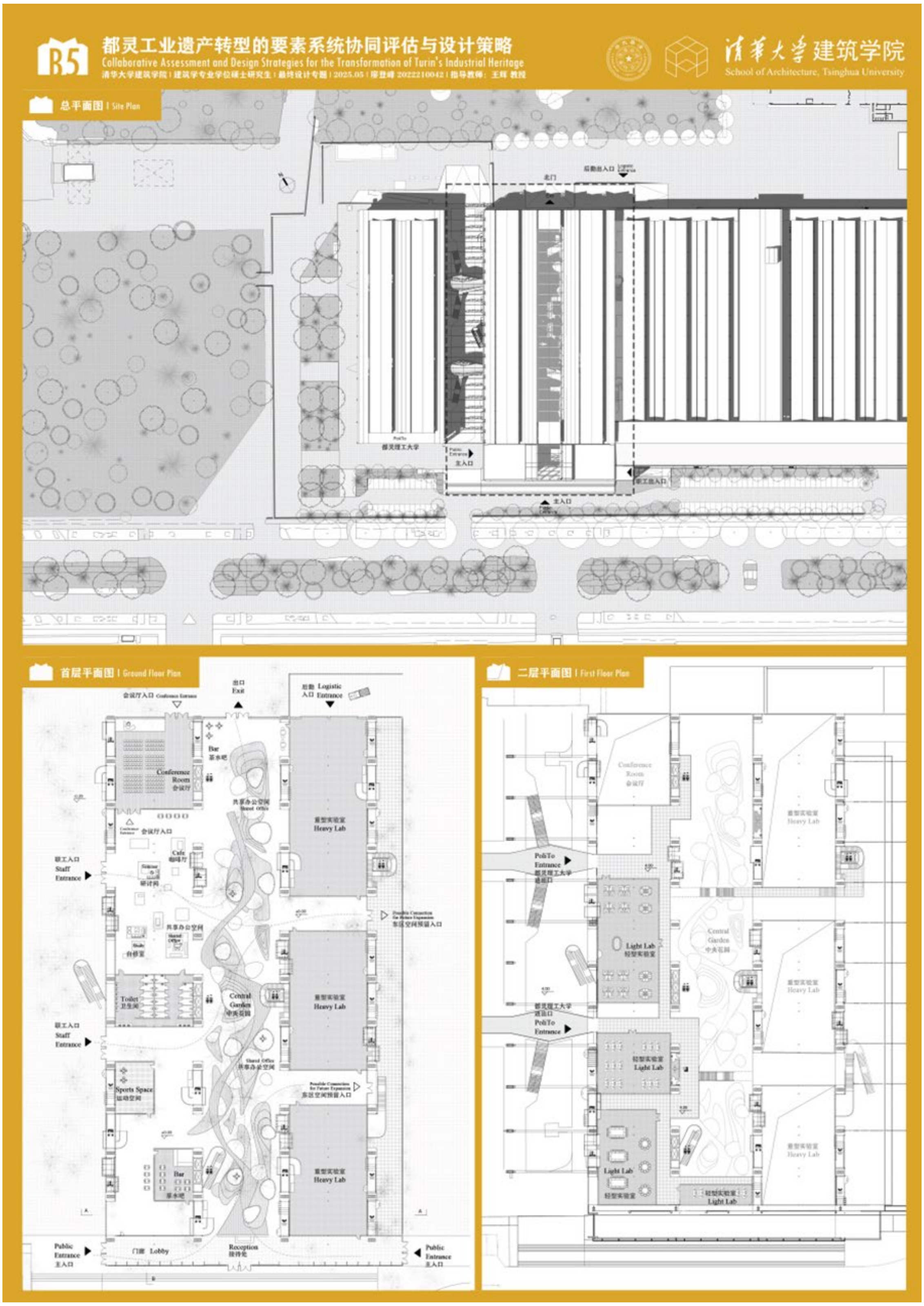
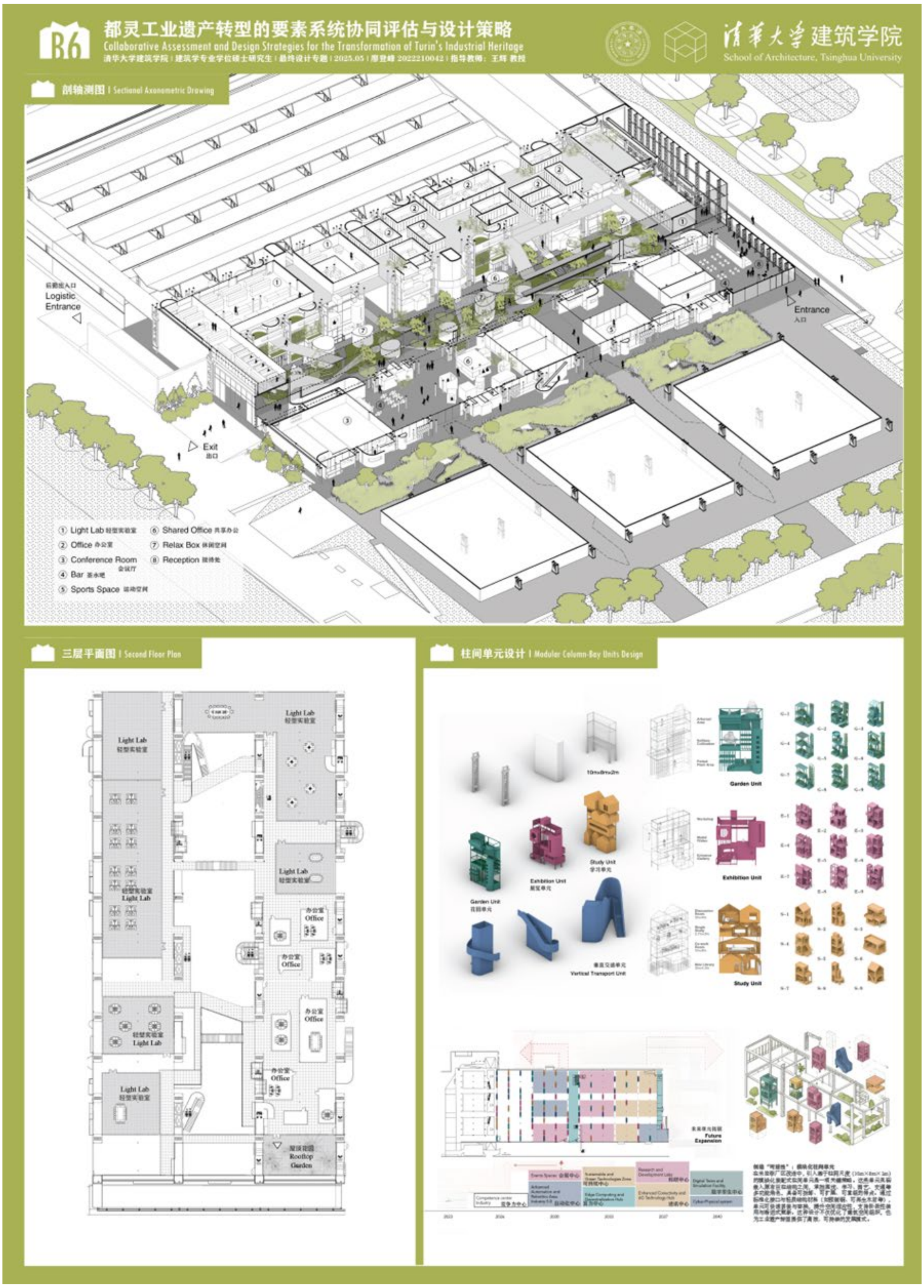
清華大學建筑学院
School of Architecture, Tsinghua University
Torino Air Club
Porta Susa
Historical Center
Martini Hospital
Politecnico di Torino
Porta Nuova
Valentino Area
Ospedale Regina Margherita
Lingotto
TORINO MIRAFIORI
N
0 500m 1km
Spina Centrale Areas
Important Public Areas
Metro Line 1
Main Roads
Railway Lines
Greenery
前期概念分析 | Preliminary Concept
History /Value
Now /Physical
Future /Function
Light Lab
Heavy Lab
Central Garden
Public Service
Rooftop Garden (Staff Only)


B5
都灵工业遗产转型的要素系统协同评估与设计策略
Collaborative Assessment and Design Strategies for the Transformation of Turin's Industrial Heritage
清华大学建筑学院
School of Architecture, Tsinghua University
总平面图 | Site Plan
首层平面图 | Ground Floor Plan
Conference Room
会议厅
Heavy Lab
Central Garden
Toilet
卫生间
Sports Space
运动空间
Bar
Lobby
Reception
Staff Entrance
Public Entrance
二层平面图 | First Floor Plan
Light Lab
PoliTo Entrance


B6
都灵工业遗产转型的要素系统协同评估与设计策略
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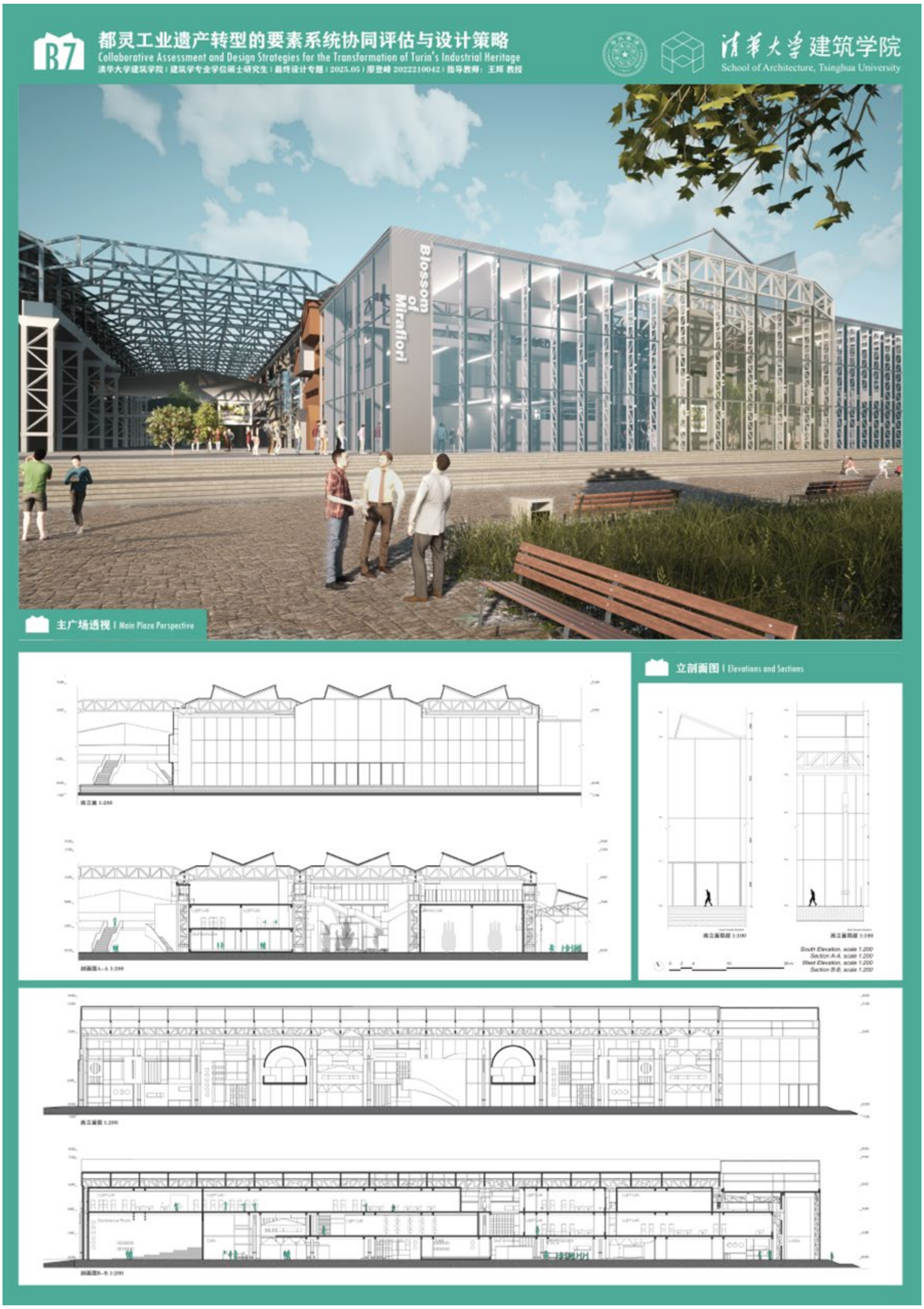
清华大学建筑学院 | 建筑学专业学位硕士研究生 | 最终设计专题 | 2025.05 | 廖登峰 2022210042 | 指导教师：王辉 教授
清華大学 建筑学院
School of Architecture, Tsinghua University
剖轴测图 | Sectional Axonometric Drawing
后勤出入口
Logistic Entrance
Entrance
入口
Exit
出口
① Light Lab 轻型实验室
② Office 办公室
③ Conference Room 会议厅
④ Bar 茶水吧
⑤ Sports Space 运动空间
⑥ Shared Office 共享办公
⑦ Relax Box 休闲空间
⑧ Reception 接待处
三层平面图 | Second Floor Plan
Light Lab
轻型实验室
Office
办公室
Rooftop Garden
柱间单元设计 | Modular Column-Bay Units Design
10mx8mx2m
Garden Unit
花园单元
Exhibition Unit
展览单元
Study Unit
学习单元
Vertical Transport Unit
垂直交通单元
Future Expansion


B7
都灵工业遗产转型的要素系统协同评估与设计策略
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清華大學建筑学院
School of Architecture, Tsinghua University
Blossom of Mirafiori
主广场透视 | Main Plaza Perspective
立剖面图 | Elevations and Sections
South Elevation, scale 1:200
Section A-A, scale 1:200
West Elevation, scale 1:200
Section B-B, scale 1:200


B8
都灵工业遗产转型的要素系统协同评估与设计策略
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清華大学 建筑学院
School of Architecture, Tsinghua University
室内中庭透视 | Atrium Perspective
场景透视 | Perspective Concept Sketch
ENTRANCE
结构层级与细部设计 | Structural Design
Structural Analysis
-hierarchy
Hierarchy under vertical load
Hierarchy under horizontal load
Conference Room
Hierarchy under vertical load