Research on the Utilization Mode of Underground Space in the Protection of Shanghai's Industrial Architecture Heritage

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Abstract. With the arrival of the era of stock optimization, urban existing industrial areas and industrial buildings through renovation and upgrading to improve the building performance and expand the building function, more and more become an important content of urban renewal. With rich industrial building heritages in Shanghai as an example, the study was based on the ground of the industrial heritage protection status and function of underground space utilization, exploring the development and utilization of underground space to realize city both with industrial zone industrial building heritages protection development, expansion of land space and function optimization, summarized based on the industrial building heritages protection of underground space utilization patterns and their characteristics. It can provide a reference for the existing urban environmental stock renewal and expansion.

1. Introduction

As urbanization enters the second half, Chinese cities have entered a new stage of industrial restructuring and optimized development of land use\cite{1}. The existing industrial areas of cities are relatively independent in general functions, and they are at the edge of the city in the initial stage of development. As the city expands, its surrounding area has gradually formed a new central urban area. However, its development was restricted by the nature of its land-use restrictions and the relative independence of its functions. This restriction is reflected in the complexity of the project subject, the diversity of congestion ownership, the location of the project, and the parameters of the city. The impact of existing industrial areas and the remains of industrial buildings\cite{2}. To solve this drawback, the State Council issued the "Decision on Deepening Reform and Strict Land Management" as early as 2004\cite{3}; after that, cities have proposed various land policies related to industrial transformation. Taking Shanghai as an example, relevant policies and regulations have been issued since 2008\cite{20} The remaining items can be roughly divided into five stages: pre-transformation, spontaneous transformation, policy guidance, standardized transformation, and activation transformation. In the process of transformation and development of existing industrial areas, along with the redevelopment of cities, especially in areas located in important urban areas, the development of underground space has gradually become the main way to protect the surface industrial culture and expand the urban space. Therefore, the research is based on the protection of industrial building remains. Shanghai’s underground space utilization model has a positive effect on the promotion of the redevelopment of...
existing industrial areas and the utilization of underground space and has guiding significance for projects with similar needs.

2. Overview of the Development and Utilization of Shanghai’s Industrial Relics
Shanghai is a well-known international industrial and commercial city in modern China, with rich industrial architectural heritage resources. They are mainly general industrial plants, heavy industrial plants, and light industrial plants concentrated along the Suzhou River and Huangpu River; in the era[4], there are mainly colonial industrial plants and modern national industrial plants. At present, the main form of reuse of the remains of industrial buildings in Shanghai is the creative industrial park. The main transformation modes include the conservation and development of excellent historical buildings, the transformation, and reuse of old industrial remains, the transformation of the original land properties of old industrial sites, and the transformation of industrial agglomeration[5]. In the 1990s, Shanghai’s industrial transformation promoted the adjustment of the urban layout. A large number of corporate offices and production sites were moved to the suburbs, resulting in a large number of industrial zones and their industrial buildings being idle[6]. The main reasons for the transformation were industrial restructuring, the continuation of historical and cultural values, and business ideas. The five aspects of adjustment, promotion of economic benefits, and outstanding social benefits (Table 1) show that there are various types of industrial heritage development in Shanghai. This study was approved by the Ministry of Science and Technology in 2018 for the green building special "Functional Upgrading and Renovation of Existing Urban Industrial Zones" Under the funding of the "Technology" project (2018YFC0704903), a special investigation and review of cases of ground-based industrial landscape protective development found that there are common causes of protective development in Shanghai that expand the space capacity through the development of underground space[7]. The investigation process tried to summarize the development and utilization model of underground space based on the protection of ground industrial heritage, which is described below.

| Motivation | Description | Types |
|------------|-------------|-------|
| 1 Industrial restructuring | Eliminate high-polluting enterprises, increase the proportion of the primary industry, and promote the development of high-tech enterprises | Industrial building upgrade type |
| 2 The survival of historical human values | Reuse the public buildings around the remains of industrial buildings with historical value, and promote the sustainable industrial style | Industrial building protection development type |
| 3 Adjustment of business thinking | Commercialized development of industrial areas located in commercial districts to inject new vitality into industrial buildings | Industrial characteristic commercial development type |
| 4 Economic benefit promotion | Improve the renovation of existing industrial buildings with low industrial production efficiency due to backward technology and technological processes | Building performance-enhancing type |
| 5 Outstanding social benefits | Transform the industrial area and its industrial buildings with complete infrastructure in the central urban area into a cultural and creative industrial park | Cultural industry transformation |

3. Investigation on the Development of Underground Space in Shanghai’s Industrial Relics
The project team has traveled to Shanghai several times to investigate the use of existing urban-industrial areas and industrial buildings. Due to insufficient network data, it is difficult to accurately know whether the existing urban-industrial areas and industrial buildings are developing underground
spaces. The project team has investigated the existing urban-industrial areas and their industrial buildings in total. There are 15 urban industrial zones (Table 2).

Table 2. Survey Summary of Underground Space Development of Shanghai's Industrial Relics

| Name                             | Type                  | Location | underground developed |
|----------------------------------|-----------------------|----------|-----------------------|
| Longhua Airport Oil Tank Warehouse | Heavy industry plant  | Central  | Yes                   |
| Coal Mine Transport Wharf        | Heavy industry plant  | Central  | Yes                   |
| Shanghai Automobile Brake Factory | Heavy industry plant  | Central  | NO                    |
| Nanhsi Power Plant               | Heavy industry plant  | Central  | NO                    |
| Yangpu Binjiang Shipyard         | Heavy industry plant  | Central  | Yes                   |
| Shanghai Aircraft Factory        | Heavy industry plant  | Central  | NO                    |
| Shanghai Baosteel No. 2 Steel Plant | Heavy industry plant  | Central  | Yes                   |
| Shanghai Glass Instrument No. 1 Factory | Light Industrial Plant | Suburbs  | Yes                   |
| Yufeng Yarn Factory              | Light Industrial Plant| Central  | NO                    |
| Shanghai Chunming Woollen Factory | Light Industrial Plant| Central  | NO                    |
| Shanghai No. 8 Cotton Textile Factory | Light Industrial Plant | Suburbs  | NO                    |
| Longhua Hangar                   | General industrial plant | Central  | Yes                   |
| Shanghai Storage and Transportation Company Warehouse | General industrial plant | Suburbs  | Yes                   |
| Hero Pen Factory                 | General industrial plant | Suburbs  | Yes                   |
| Taopu Industrial Zone            | General industrial plant | Suburbs  | Yes                   |

Among the 15 existing urban industrial zone renewal projects, 7 of the surface industrial buildings are heavy industrial plants, 4 of the projects for the development of underground space, accounting for 57%; 3 of the light industrial plants, and 0 of the projects for the development of underground space; general There are 4 industrial plants, all of which have developed underground space; 10 of the 15 survey subjects have developed underground space, accounting for 66.6%. It can be seen that different surface industrial building structures have a greater impact on the development of underground space. The foundation of heavy industrial plants is complex but strong, and underground space development can be appropriately carried out. Light industrial plants are generally small in scale and shallow in the foundation, which exerts forces on the surrounding soil. The demand is large, so it is generally not suitable for underground space development. Generally, industrial plants are somewhere in between. Therefore, generally, such industrial buildings are renovated and suitable for underground space development.

Existing urban industrial areas, as industrial historical relics, possess distinctive cultural and historical resources, and are an important part of the urban or regional landscape. The development of their underground space has added some functions to better highlight the location and the image of the city. Bringing many opportunities for differentiated development of cities. Through the development and utilization of underground space, while protecting the urban texture on the ground, also makes up for the lack of space, expands the city's capacity, drives regional development, and promotes the better realization of renewal. Table 3 lists the types of underground space functions in the existing urban industrial areas in Shanghai. The most common functions for developing underground spaces in existing urban industrial areas are underground parking and underground commerce. This aspect is the protection of the surface features of the existing urban industrial areas. Driven by the appropriate amount of commercial development, it has also promoted the improvement of the economic benefits of existing urban industrial zones. Combined with the case situation in Table 2, it can be seen that
multi-functional development of underground space development functions based on satisfying parking and commerce is an important way to improve the overall effectiveness of existing urban industrial zones.

Table 3. Types of functions of underground space in existing urban industrial areas

| Cases                      | Transportation | Exhibitio | Commercial | Other public space |
|----------------------------|----------------|-----------|------------|-------------------|
|                            | Underground parking | Underground road |            |                  |
| Long Museum                | √               |           | √          | √                 |
| Oil Tank Art Center        |                |           |            |                   |
| Internet treasure          | √               |           | √          | √                 |
| Binjiang Shipyard          |                |           |            |                   |
| Zhongcheng Zhigu           |                |           |            |                   |
| Hero world                 |                |           |            |                   |
| Taopu Central Park         |                |           |            |                   |
| Yuz Museum of Art          |                |           |            |                   |
| Yuz Museum of Art          |                |           |            |                   |
| Shanghai Museum of Glass   |                |           |            |                   |

Although underground parking and underground commercial development are common development methods in existing urban industrial areas, it is not difficult to find that there is an obvious alignment relationship between underground space and ground space, as shown in Figure 1. The selection of underground space functions corresponding to these different modes is affected by many factors. For example, from the perspective of regional development, when existing urban industrial areas that have been renewed are at the center of future urban development, simply look at the space requirements at this stage. Setting out for underground space planning and design is obviously difficult to meet the needs of future development. Urban traffic development trends corresponding to different traffic conditions also have a significant impact on the underground space development of existing urban industrial areas. Therefore, the use of scientific methods to simulate the evolution of the spatial structure of existing urban industrial areas is to judge the current and future development of existing urban industrial areas. The scientific basis for the development of underground space in existing urban industrial zones is needed and determined.

4. Analysis of Shanghai Industrial Relics and the Development Mode of Underground Space

Through the above survey and analysis of the existing urban industrial zones and related industrial buildings in Shanghai, it can be seen that the types of reuse of the existing urban industrial zones with the protection value of industrial architectural heritage mainly include theme museum exhibition halls, industrial heritage park landscape enhancement, and business Five forms of office function enhancement, characteristic industrial cultural tourism and comprehensive development model.

4.1. Theme Museum Exhibition Hall Mode

The utilization mode of the theme museum exhibition hall refers to the special exhibition of certain technological production processes or the transformation of the characteristic exhibition hall of the original industrial building according to its spatial characteristics and structural restrictions. While revitalizing the architectural function to reproduce the sense of history and authenticity of the building, it also reflects the shaping of the city's characteristic culture and style. The more well-known projects include the transformation of the German Henry Steel Plant built-in 1854 into an open-air industrial museum, and the Long Museum is an art exhibition hall transformed from the original coal mine transportation terminal (Figure 1). Industrial equipment is preserved on the periphery of the building. The industrial park of the project has been strengthened, and its underground space development functions include underground parking (Figure 2), equipment rooms, etc.
4.2. Landscape improvement mode of industrial heritage park

The landscape improvement model of the industrial heritage park uses the characteristics of the site and the abandoned space for redevelopment and transforms it into a heritage park with an industrial heritage. The more famous projects include the Beijing Shougang Industrial Park Relic Park and the Seattle Gasworks Park in the United States. The transformation model is suitable for existing industrial areas in cities with empty sites and intact industrial components and facilities. Shanghai Yangpu Binjiang Shipyard will be transformed into the main venue of the Urban Space Art Season in 2019 (Figure 3). Among them, the use of its original sinking space for public space transformation has greatly enriched the spatial interest of the venue (Figure 4). Reconstruction with sinking space is also a cost-effective space reconstruction plan.

4.3. Business office function enhancement mode

The business office function improvement mode is to use the factory building to transform into a business office area with industrial features. The amount of renovation projects depends on the specific space capacity requirements and commercial value. This transformation mode has a higher positioning of the business model and the content of investment promotion. It is required that a good transformation model provides collaboration opportunities for a variety of creative industries to achieve the transformation effect of one plus one greater than two. The commercial value level is to attract creative industries to settle in, and guide regional renewal and appreciation through qualitative use modes such as leasing and transfer. This model is currently the most popular method in China. The more well-known ones include Hangzhou Hangyin Road L0FT49, Shanghai No. 8 Bridge Creative Park, Guangzhou TIT Textile and Garment Creative Park, and so on. Zhongcheng Zhigu is transformed from the warehouse of Shanghai Storage and Transportation Company. In addition to protecting the ground industrial buildings, it develops office and commercial facilities in spare locations to provide new space for the renewal of the industrial area (Figure 5). Its underground space function is underground parking, equipment room, etc (Figure 6).

4.4. Characteristic industrial cultural tourism model

The characteristic industrial cultural tourism model takes advantage of the large-scale space of the production workshop and transforms it into a commercial shopping center or a cultural and artistic center. For example, the Centro Shopping District in Oberhausen, Ruhr, Germany, transforms huge industrial equipment into a shopping mall or an art center, which has both the commercial characteristics of shopping and the art-viewing characteristics and is equipped with cafes and bars, Gymnasium, clothing city and children's entertainment venues, and other functions. Shanghai Yuz Art Center is transformed from the original Longhua Hangar, a large-span factory building (Figure 7). Its underground space is equipped with underground entertainment space, public activity space, and exhibition space according to needs (Figure 8).
5. Summary of Shanghai’s industrial remains and its underground space characteristics

Shanghai’s industrial remains have a long-lasting existence, rich style, and features, and have extremely high protection and reuse value. The rectification measures for its industrial remains and the characteristics of underground space development are summarized as follows:

5.1. Renovation and renovation measures of Shanghai’s industrial remains

(1) For the existing industrial buildings with protection and reuse value, repair and protect the architectural image characteristics and industrial components of the industrial relics, so that their industrial characteristics can be fully displayed. Pay attention to the protection, restoration, and redesign of the historical environment, historical features, and historical atmosphere of the industrial heritage. For example, the factory and office buildings, pipelines, industrial machinery, and equipment should be kept and refurbished as much as possible to maintain the overall industrial outlook. Youmei strengthens the maintenance and repair of the facades of buildings with better appearance, which is a design method commonly adopted by most industrial creative parks and industrial parks. Take cleaning, reinforcement, and partial repair to fully maintain the original appearance of the building’s facade, and try to maintain the sense of history and industry of the building.

(2) Regarding the spatial layout of the existing industrial areas in the city, focus on the reorganization and utilization of the internal space of the building. On the premise of maintaining the facade style of the building, the larger volume and open space scale of the industrial building are used to reorganize and layout the spatial functions. Adjustment. Various measures such as corridors, partitions, additions, and removals are often used to achieve the purpose of enriching the spatial form, increasing the spatial interest, and adapting to the use of functions.

(3) Rectify and upgrade the rest of the external space pattern and landscape environment. Through the transformation of the external landscape environment, supporting facilities, and public space, the original closed and single factory environment will be shaped into a strong openness, high participation, and rich space. A characteristic space with unique cultural charm. The preservation of industrial landscape elements and the implantation of modern urban landscapes enable the organic integration of landscape environment and cultural atmosphere.

(4) Combine protection and utilization, introduce new functions, and restore vitality. Generally, according to the value, culture, and current conditions of the industrial heritage, it will be transformed into various functions such as cultural facilities, industrial bases, small community complexes, art centers, and heritage landscape parks. Realize the renewal and utilization of the site through function replacement and industrial cultivation.

5.2. Underground space development characteristics

Through the investigation of the existing urban industrial parks and their industrial buildings in Shanghai, it is found that the existing industrial parks with underground space development mainly have transportation functions (including rail transit, underground dynamic transportation, and underground parking) and equipment functions. Cultural functions (museums, cultural centers, etc.), commercial functions (underground commercial streets, underground restaurants, shops, etc.), underground equipment functions (equipment rooms, substations, etc.), and related underground spaces such as daylighting patios, sunken squares, and atriums Quality-enhancing functions. In its
underground space development function, underground parking space and equipment space are similar to general engineering projects. The setting of these underground functions has a more direct effect on the protection of the ground style and features for existing urban-industrial areas and industrial buildings. As for the setting of other functions, it has a greater relationship with the project location, ground development mode, and development function. The renewal of existing urban industrial areas in downtown areas has more urgent demands for underground space development, so the developed underground space functions are more diverse. The same type of development projects have smaller functions and scales in the urban suburbs of the underground space; large-scale workshops and large-span workshops have fewer structural restrictions, and the internal development of underground spaces provides more favorable conditions for the reuse of buildings. The existing urban industries with empty bases The development of underground space in the district is less difficult.

6. Conclusion
Based on the above investigation and analysis, it can be known that the development of underground space in the process of renewal and transformation of existing urban industrial areas can promote the underground nation of some surface facilities and improve the environment on the ground; on the other hand, underground space provides necessary parking for the area. It can be considered that the development of underground space provides sufficient space resources and necessary environmental value for sustainable development in the renewal of existing urban-industrial areas and industrial buildings. It needs to be pointed out that the underground space development in the existing industrial parks of cities is different from the general development and construction activities. It receives multiple influences such as the style of the ground building, the structure and basic conditions of the ground building, the location of the industrial area, and the actual needs of the project. During the development of the project, evidence should be collected extensively, carefully verified, and fully verified, and its underground space development function positioning, function mode, and function scale should be in-depth demonstrated, and scientifically guided the rational development of existing urban-industrial areas and their ground industrial building remains.

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