Conservation and adaptive reuse of modern military industrial heritage: a case study on the former site of Jinling Arsenal in Nanjing, China

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ABSTRACT
To strengthen its power and resist aggression, the Qing-dynasty government of China began building military-industrial bases after the Opium Wars and to learn advanced Western science and technology. Through nearly 150 years’ development, the former site of Jinling Arsenal has become the largest and most representative architectural group of modern military industrial heritage buildings in China. This paper analyzes the history and heritage characteristics of the site. It is found that under the exchanges and conflicts between Chinese and Western civilizations, the military architectural heritages reflect remarkable characteristics of pioneering and integration of Chinese and Western architectural styles, spatial forms and construction technologies, as well as the intrinsic traits of mixing and transition of structure, based on guiding ideology of “Chinese essence and Western utility”. These heritages not only show the influence and restriction of political goal on construction technologies, but also become the identity representation of the country, city and proprietors, thus having unique meaning and value. In addition, the corresponding methods and strategies, repair techniques and existing problems are discussed through the critical analysis of the conservation and adaptive reuse of typical heritage buildings, so as to provide basis and beneficial reference for related research and practice.

1. Introduction
Compared with the western countries, there was no industrial revolution in China in the 19th century. At that time, the Chinese society was still an agricultural and semi-feudal society. With the failure of the two Opium Wars, the late Qing Dynasty was forced to carry out social reform and national self-improvement movement, put forward the strategy of “learning from foreigners to control foreigners” and turned to learn advanced science and technologies from the west, trying to make it as a part of China’s local system to resist foreign aggression (Peter and Kuan 2004). In this context, the late Qing government invested and hired Western engineers to design and build a number of military industrial bases. The related western industrial production technology, industrial construction technology and facilities and equipment appeared in China for the first time, representing the highest level of domestic industrial production and construction technology at that time (Ji and Wang 2015), and these even were considered as the beginning of China’s modern industrial revolution. However, due to the backward production conditions and social development level of China at that time, faced with the sudden introduction of new things, it was difficult to implement them completely in accordance with the requirements of the construction technologies under western industrial civilization. At the same time, the late Qing government retained the illusion of continuing its rule through sticking to the tradition (Sun 2000). Therefore, those western production methods and construction technologies made concessions and compromises to the actual situation in China during the process of being introduced, adapted, and integrated with local conditions. This also demonstrates the influence of modern Western civilization on Chinese traditional civilization, and China’s response to the impact of western industrial civilization (Pan and Campbell 2018).

Jinling Arsenal (formerly known as Jinling Machinery Bureau) was built in 1865 by Li Hongzhang, a famous minister of the late Qing Dynasty who was the governor of Jiangnan and Jiangxi Provinces at the time. It is a typical representative of modern military industrial construction in China. After more than 150 years of vicissitudes, its function of military industrial production, distinctive industrial buildings, and its quiet environment have been preserved. Today, it has become a built environment that combines the characteristics in three historical periods of the late Qing Dynasty, the Republic of China, and the People’s Republic of China. At present, the former site of Jinling Arsenal retains most of the industrial relics that were put into production in the past, including
production plants, warehouses, workers’ schools and some facilities and equipment. As described in the Nizhny Tagil Charter (TICCIH 2003), these relics reflect the political and social changes and the development of science and culture in China over the past few hundred years, and they have high historical, social, technological and architectural scientific values. The factory area has been selected not only as one of the seventh batch of national key cultural relics protection units under the name of “former site of Jinling Arsenal” in 2013, but also as one of “China’s 20th Century Architectural Heritage Projects (the second batch)” and “China’s Industrial Heritage Protection List (the first batch)”.

The former site of the Jinling Arsenal was located outside the Zhonghuamen Gate in the ancient city of Nanjing. It was a military industrial relic hidden in lush greenery, which was adjacent to the magnificent walls of Ming Dynasty and adjacent to the Grand Baen Temple Site Park in Jinling (Figure 1). With the development of Nanjing, industrial production within the urban area was gradually moved out. In view of the important location conditions of the former site and the multi-level value of the precious building remained, the original main unit of the factory hoped to continue to control the use right of the plant area and bring new benefits, while the local government hoped to make full use of the resources of the plant area to obtain higher taxes to drive the regional economic development, and to change the city’s appearance. Therefore, they jointly established Chenguang 1865 Real Estate Investment Management Co., Ltd. (65% of the group’s shares and 35% of the government’s shares). Under the condition that the nature of the land (state-owned) and the building use right (Chenguang Group) remained unchanged, the government and enterprise cooperation mode is adopted to protect and reuse the former site of Jinling Arsenal. Chenguang Group is responsible for the protection and construction, investment attraction and operation management of the old site, while the local government plays the role of policy support, tax preference and part of investment attraction.

Through the investigation and study of historical records, government documents, historical maps, research documents and other materials related to the Jinling Arsenal, this article demonstrates the conflicts of civilizations under the asymmetric exchanges between China and the West as reflected by this group of military industrial heritage clusters, and the special architectural heritage characteristics formed by the combination of the long cherished wish of modern Chinese political body and the western advanced industrial technologies. At the same time, this article selects typical architectural cases, summarizes and critically thinks about the protection and adaptive reuse practices of the Jinling Arsenal site heritage, and discusses the feasible strategies for the conservation and reuse of such modern military industrial heritage, the reliable techniques for the conservation and repair of architectural heritage, as well as the existing problems, so as to provide the basis and beneficial reference for related research and engineering practice.

2. Brief history of the Jinling Arsenal

2.1. Late Qing Dynasty: built by the river, the scale has begun to take shape

In the fourth year of Tongzhi (1865), Li Hongzhang “bought civilian residences and built the Artillery Bureau on the east end of Saozhou Alley outside the South Gate”(Nanjing Publishing House 2011). The main reason for choosing this place was convenient transportation. It was close to the city center, city gate, and the outer part of Qinhuai River, and was connected to...
the Yangtze River, which was convenient for water and drainage of industrial production, water transportation of raw materials and products, and commuting of workers in the city. Meanwhile, it was located outside the city wall, effectively avoiding the impact of accidents in the arms laboratory on the surroundings, and the place was hidden, which was conducive to military production\(^1\) (Figure 2).

The first round of construction of Jinling Machinery Bureau was completed in July of the fifth year of Tongzhi. There was one main machine room, ninety-three halls, five pavilions, six assistant rooms, two gatehouses, and more than 200 craftsmen. In the second year after the Sino-French War (1866), the government approved Guoquan Zeng, the governor of Jiangnan and Jiangxi Provinces, to invest more than 100,000 yuan in silver for the expansion, which took one year and four months. After the expansion, there were five machine factory buildings, as well as firearm workshops, two iron-foundry workshops, two wrought iron workshops, two woodworking factory buildings, steam stove rooms, eight large chimneys, and an iron pool in Jinling Machinery Bureau. The additional equipments were mainly from the United Kingdom, Germany and Switzerland, which were the most advanced countries at the time (Charles 1899). At this point, Jinling Machinery Bureau became a large-scale modern military enterprise with nearly 1,000 workers and the scale of production was second only to Jiangnan Manufacturing Bureau (Figures 3 and 4).

2.2. During the Republic of China period: adapting measures to local conditions, gradually forming a system

After the establishment of the Republic of China, the function of military production continued here. In 1928, Chenggan Li served as the director of the factory. With the aim of “saving the nation by industry”, he began to reorganize the factory. From 1934 to 1937, two large-scale land expropriation projects were carried out on the western and northeastern sides of Majia Mountain, which brought a new look to the factory. The factory area increased from 76,000 square meters to 224,700 square meters, and the newly built and renovated building area was about 50,000 square meters. The new construction included mortar factories, tool factories, heavy machine gun factories, equipment factories, iron-foundry factories, gas mask factories, iron factories, wood factories, power plants, material laboratories and office buildings of the factory headquarters, as well as staff dormitories, hospitals, residences, children’s schools, etc., which were fully functional (Cao 2007). Moreover, its spatial layout had

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\(^1\)According to Liu Kunyi’s “Memorial of the Number of Machines and Annual Production of Ordnance in Jinling Machinery Bureau and Jiangnan Manufacturing Bureau and Proposed Expansion of Manufacturing Machinery”, “Hinterland is a favorable geological position. Once something happens in the coastal areas, it is still necessary to manufacture here to help with the military supplies and meet the military needs”.

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**Figure 2.** Location Map of Jinling Machinery Bureau.
3. Characteristics, meanings and critical cognition of the former site of Jinling Arsenal as heritage

3.1. Architectural characteristics

There are more than 40 buildings in the former site of Jinling Arsenal, which were built in different historical periods from the late Qing Dynasty to the Republic of China to the 1980s (Figure 6). The cluster of historical buildings in the former site vividly shows the development trajectory of China’s modern industrial architecture.

3.1.1. Buildings in the Qing Dynasty

Currently, there are seven buildings in use, all of which are basically well preserved and precious. The main machine factory (1866), the right machine factory (1873), and the left machine factory (1879) were placed side by side in the east-west direction during the early construction period. They were disassembled and rebuilt on the south side of Majia Mountain during the Republic of China period. The other four buildings are the Curling copper factory (1882), the Melting copper factory (1882), the large machine factory (1887) and the wood factory (1887). The main gates of these buildings all opened to the north, facing the Qinhuai River, the main transportation channel of the time. The layout corresponds to the production process: For example, the large machine factory was a processing place for firearm triggers and mechanical parts. Melting copper factory and Curling copper factory were connected for melting and casting barrels and guns respectively. The wood factory building on the east was used to produce wooden parts such as butt stocks and gun stocks. The buildings in the Qing Dynasty were constructed under the leadership of British consultants Magri and Polish Goethe. While referring to the style and pattern of British industrial buildings, the construction combines the Chinese traditions.

(1) Architectural styles were combination of Chinese and the west: For example, the roof truss was not a steel roof truss system commonly used in British industrial buildings in the same period, nor was it a traditional Chinese pure wooden roof truss. Instead, it was a triangular roof truss composed of iron...
and wood. The compression bar was a wood structure with a large cross-section, while the tension bar was an iron component with a small cross-section. Such a structural system was more reasonable with a larger span. There were European semi-circular brick arch coupons on doors and windows. The facade was a traditional Chinese plain brick wall with a green tiled roof of four slopes (Figure 7).

(2) The scale of building spaces was large. Taking the best-preserved large machine factory which had two stories as an example, the length and width of the building were 47,800 millimeters and 16,600 millimeters respectively, and the eaves height was 8,900 millimeters. The size of the black bricks used for the outer wall was about $280 \times 140 \times 80$ millimeters, and the thickness of the wall was 800 millimeters. Wooden beams on the first floor and the lower chord beams of
the second-floor truss were all imported Douglas fir wood with a section of about 400 × 420 millimeters rectangle. The second floor was made of solid wood with a width of 300 millimeters and a thickness of 70 millimeters.

(3) The application of new structural technology was pioneering. The brick wall load-bearing system was introduced in the Qing Dynasty factory buildings, which could be regarded as the beginning of the transformation of the beam-column structure system in which the building load-bearing structure and the space enclosing structure had been separated for thousands of years in China. Cast-iron pillars were used in the first floor of the large machine factory and the left machine factory. The lower chords of the first-floor wooden beam and the second-floor triangular roof truss in the large machine factory were all tensioned by reversed cables, and the tension was applied by twisting the basket bolts. This was the earliest example of “beam string” structure currently found in China. This structure significantly enhanced the function of cables and vertical supporting members, greatly reduced the cross-section size of the upper chord wooden beams or wooden roof trusses, and optimized the force characteristics of metal and wood material (Figure 8).

3.1.2. Buildings in the Republic of China

Compared with the buildings in the late Qing Dynasty, most of the buildings in this period were still in the form of plain brick walls and sloping roofs. Meanwhile, there were many new changes and characteristics:

(1) Diversified architectural functions. After several expansions, Jinling Arsenal was multi-functional and well-equipped, and became one of the most important military factories during the Republic of China. At present, the preserved buildings were 15 factory buildings, 4 office buildings, 1 storehouse, 3 dormitory buildings, and 1 ordnance school. Buildings with diverse functions had not only become valuable examples of modern military factories but also helped us understand the production and living conditions of the military industry at that time (Figure 9).

(1) In the buildings of the Republic of China, the brick and wood structure system only appeared in two office buildings. Most buildings had brick-concrete structures with brick walls, reinforced concrete slabs and wooden trusses; More than 9 buildings adopted reinforced concrete beam-less floor slab structure system, which reached more than half of the total number of factory buildings in this period. The tops of the columns on the first floor of these buildings were gradually enlarged and connected with the floor whose thickness was up to 200 millimeters (Figure 10). The longitudinal forced bars of beams and columns were made of knotted bar iron. There were no columns on the second floor, and the roof truss was a Hao-style roof truss with metal tie rods and connectors. Two zigzag buildings built in 1936 adopted the steel-wood mixed structure (H-shaped steel column net supporting triangular light steel roof truss, wood purlin and wood

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Figure 7. Sectional View of the Large Machine Factory.

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2The concept of beam string structure was first proposed by Japanese professor M. Saitoh in the early 1980s. It is named after the basic form of “the string is tensioned by the struts”, which is a new mixed system that differs from traditional structures. Beam string structure is a mixed structural system composed of rigid member upper chords, flexible cables and intermediate connecting rods. Its structure is a new self-balancing system, a large-span pre-stressed spatial structure system, and a relatively successful creation in the development of mixed structure system. Beam string structure system is simple, the force is clear, and the structure forms are diverse, giving full play to the advantages of rigid and flexible materials.
sheathing, tiled roof), with clear structure system, slender components and structural beauty.

(3) The changing of the structural types. From the construction of the factory, the evolution of cement and reinforced concrete materials technology, from partial improvement and application to gradual improvement and systematic application after its introduction into China, was evident: Initially, the concrete was applied to individual components of the buildings, such as stairs, concrete columns, and concrete floors, etc. It had gradually developed into a mature reinforced concrete structure and steel structure with a complete structural system (Figure 11). As a transitional steel-wood mixed roof truss system introduced from abroad and evolved from wooden roof truss to steel roof truss in the Republic of China, Hao-style roof truss was widely used in factory buildings in this period.

In common with the architectural heritage of late Qing Dynasty, the distinctive non-standard and transitional characteristics of building structures were showed in the architectural heritage of the Republic of China. Steel components of Western industrial buildings were mixed with Chinese traditional wood components, forming a building structure system neither newly Western nor traditionally Chinese. These characteristics reveal a gradual process in which the traditional beam-column bearing structures system was changed to realize large-span building space and new material technologies were introduced.
This process also led to imperfections of the transitional structural systems of many heritage buildings.

### 3.2. Meanings of heritage

Architectural heritage breaks the time-space boundary, records the material environment of social, economic and cultural changes with the objective characteristics of individual or group, and continues that (Aysegul 2016). The significance of the former site of Jinling ordnance factory as a heritage is extensive and profound. On the one hand, it contains the identity representation of the state, the city and the proprietors in the fields of subject (Barber 2013), which originates from the connection between the past history and the future consciously established by the overall image of the heritage. First of all, the Jinling Armory is an involuntary product that the late Qing government was forced to try to achieve the goal of self-reliance by learning advanced technologies from the West. As an important part of the process of modern history, it was born with the label of national will. Secondly, Nanjing occupies an important position in the modern history in China. As an earlier opening city, it not only took the lead in commercial and cultural exchanges with western countries, but also was the capital of the Republic of China government. As the most complete modern military building complex in China (Xu 2016), the former site of Jinling ordnance factory was different from historical sites and contemporary urban features, recording the modern characteristics of the blending of Chinese and western styles of Nanjing urban buildings. As far as the enterprise itself is concerned, the status of Jinling ordnance factory has changed from bureaucratic capital military industry to state-owned manufacturing industry in more than 150 years, which has accumulated unique social process characteristics. From the process of its transformation and reuse since this century and the fact that it was named "1865 Chenguang Creative Industrial Park" which highlights the historical time node, it is clearly seen that the past of heritage represents an identity, which is branded by enterprises and becomes the capital to expand its attraction.
On the other hand, historical consciousness, as the essence of heritage significance, reflects the political will of the ruling class shown by the fusion and transition of architectural culture between Chinese and western civilizations in the state of unequal communication since modern times. As mentioned above, there are irreconcilable contradictions in the self-improvement movement of the late Qing government, that is, the strategy of “Chinese body and Western function”, not only wanted to retain the feudal system, but also wanted to learn the advanced western technologies (Li 2015), which implied the illusion of restoring the ruling authority through traditional forms. Compared with the thorough industrial revolution in the west, this kind of advanced technology learning objectively based on the backward political system and subjectively based on the ideal model constrained by realistic conditions, resulted in the characteristics of modern architecture under the interaction of political intent and foreign technology. As a typical representative of this kind, Jinling Arsenal truly reflected the historical fact of the conflict between reality and ideal in terms of building’s shape, material, structure and technology. Although western engineers and craftsmen were employed at the beginning of the construction, the traditional Chinese architecture was still used in the workshop. As a result, it was difficult for the wood structure system to match the large space of industrial production (Figures 12 and 13). In 1887, the western brick wall bearing system was adapted, and the four slope roof, arch gate, glass window and other formal elements were introduced to meet the functional requirements. However, the western industrial construction system was not fully accepted. Instead, the mixture and localization of architectural structure and form appeared in combination with Chinese tradition (Chen 2018). Just like a series of political movements in the late Qing Dynasty, these sudden and unique architectural phenomena did not continue, but only as a kind of change and transition of rise and fall, which achieved a certain level of history. It was not until the period of the Republic of China that the influence of political will on technology gradually faded out, and more mature industrial building systems such as large-span reinforced concrete and steel structure appeared in the factory buildings. In the face of the impact of western civilization, the instability of the ruling class’s internal ideological structure and the continuity of external phenomena made the existing modern buildings in the Jinling Arsenal rich and unique in terms of form, structure, material technology, etc (Table 1).

3.3. Critical cognition of conservation and adaptive reuse

As a historical record, heritage buildings are important objects for embodying cultural identity and cultural experience (Smith 2006). Their tangible connection with the past provides a fabric that allows future generations to acquire historical significance and cultural identity. When conservation is sensitive to urban context, previous uses, traditional materials and methods, the potential to understand the past through the built forms is revealed. Facing the conservation of the Jinling Arsenal located in the core area of the urban

**Figure 12.** The Newly Built Arsenal with Chinese Tradition.

**Figure 13.** The Narrow Workshop Space in the Early Period.
Table 1. Summary of Relics and Buildings in the Former Site of Jinling Arsenal.

| Construction date | Initial functions | Overall structural systems | Main structure and technical characteristics | Quantity of remains | Representative buildings |
|-------------------|-------------------|---------------------------|---------------------------------------------|---------------------|--------------------------|
| Late Qing Dynasty | Factory building  | Brick wood structure      | Brick wall load-bearing                      | 5                   | E9, B2, B3, D6, E11     |
|                   |                   | Steel-wood mixed structure| Brick wall load-bearing                      | 2                   | A8, B1                  |
| The period of the | Factory building  | Brick concrete structure  | Brickwall bearing, reinforced concrete floor | 4                   | D2, D3, D4, E16         |
| Republic of China |                   | Reinforced-concrete structure| Hao-style steel-wood mixed roof truss       | 9                   | A5, A7, A10, A9, A11, E7, E8, E13, E15 |
|                   | Storehouse        | Mixed structure           | H-shaped steel column, triangular light steel roof truss | 2                   | A1, A2                  |
|                   |                   |                           | Brick-concrete structure on the east side, Reinforced concrete structure on the west side | 1                   | E14                     |
|                   |                   |                           | Brick wall bearing                           | 2                   | A3, E12                 |
|                   |                   |                           | Wooden floors, wooden roof trusses          | 2                   | A12, D5                 |
|                   | Dormitory         | Brick concrete structure  | Horizontal brick wall bearing                | 2                   | A13, A14                |
|                   |                   | Reinforced concrete structure| Reinforced concrete floor                   | 1                   | A15                     |
|                   | School            | Brick concrete structure  | Reinforced concrete beams, columns and floors | 1                   | A16                     |

area with unique value and various forms, it is necessary to pay attention to the more subtle meaning behind the special form of each unit and the purpose of maintaining diversity. Such protection should be based on respect for the existing structure, use, connection and meaning, and make as few unnecessary changes as possible. It should not distort the material evidence of the heritage, nor should it be practiced based on guesswork (ICOMOS 2013). The primary goals of the protection of architectural heritage is to make the heritage itself obtain better safety, durability, and the integrity of all components including appearance and interior (ICOMOS 2003). "Venice Charter" (ICOMOS 1964) emphasizes the authenticity of the materials in the restoration of the heritage and the interesting parts of the building composed of the traditional setting relationship, the balance relationship of the components, and the surrounding relationship, as well as the understanding and establishment of authenticity based on different cultural backgrounds emphasized in the "Nara Document" (ICOMOS 1994). All these have profound theoretical explanations for the presentation of meaning in heritage conservation and renovation. In fact, as far as the conservation of the former site of Jinling Arsenal is concerned, it is not a purely monumental protection. It needs to be based on a series of charters and principles to ensure that in the protection of a holistic space, different heritage buildings are intervened in a more prudent way to express the historical characteristics and to explore the potential of the contemporary era.

In the process of reuse, it is necessary to carry out some transformations of the architectural heritage, including architectural structural intervention, material maintenance, spatial layout, functional replacement, and even site redevelopment (Tsai 2018). The functions of the military industrial production in the past need to be replaced, which means the transformation of the original state of the internal space and the exploration of the potential to meet the new functional requirements. From the material level of architecture, on the one hand, it is required to continue the historical tradition in the form of architecture, and to restore the history and show it; on the other hand, it is necessary to take the full advantages of contemporary design methods and technologies, and emphasize the contemporary contribution (Guo and Zhao 2020). From the perspective of heritage significance, although the original function is no longer important and needs to be negotiated with the completed form in the process of reconstruction and reuse of heritage buildings on the former site of Jinling Arsenal, the significance of heritage identity representation and architectural culture reflecting historical consciousness is positive. It has the functions of explaining history and recording civilization. This negotiation process should not be regarded as ignoring and suppressing the original history, nor should it establish new uses to weaken and cover up the past, or deliberately change the expression of heritage meaning (Pendlebury, Wang, and Law 2017). On the contrary, how to fully present the significance of the military heritage in the process of reuse, and integrate the requirements of contemporary creative industries and office space were paid more attention, so as to that the history of the heritage itself in the new urban environment was not only commemorated, but also on the basis of ensuring the safety and
integrity of cultural relics. It is necessary to endow them with reasonable use functions to make them reappear vitality, integrate them into the process of urban space and social development, and achieve the goal of sustainability (Shih and Yen 2018). This is exactly the adaptive reuse which we are pursuing.

4. Practice of conservation and adaptive reuse
4.1. Evaluation of values
International Charters and the government’s cultural relic protection standards indicate that value evaluation is essential to protect the heritage.

4.1.1. Historical value
In the former site of Jinling Arsenal, the factory buildings in the late Qing Dynasty, the Republic of China and the different periods after the founding of the People’s Republic of China have remained intact and structurally clear. It not only vividly demonstrates the historical track of the early stage of China’s modern industry and the development of China’s manned space engineering and other military industries in the new century, but also serves as an important historical witness of China’s Westernization Movement, the Republic of China’s War of Resistance, the War of Liberation and the peaceful development. The former site exudes a refreshing historical atmosphere, which is praised by scholars as the important heritage with “shining humanity”.

4.1.2. Creative value
As the most complete remains among the “four major arsenals” in the late Qing Dynasty and the arsenals of the Republic of China, Jinling Arsenal’s former site is an important physical achievement of the development of modern military industry and architecture in China. Its architectural structure and material technology are pioneering and clear in development. The whole factory area can be regarded as the “living fossil” and “exhibition hall” of the development of modern industrial buildings and materials technology in China. The era styles of combining indigenous and western, the unique spatial characteristics of industrial buildings and its pursuit of high efficiency and standardization, and the pioneering structural combination of building materials such as brick, wood and steel, all reflect the artistic aesthetic standards of simplicity and little decoration of modern industrial architecture in China. They are also specimens of the study of construction technology at that time.

4.1.3. Reuse value
Most of these industrial heritages differ from civil heritage buildings in that they have strong structures, are spacious, and are of high construction quality. Although the original production function has been withdrawn, their space, structure, and site service life have the potential to be continuously used. Sites, structures, and production equipment can be used as the public space and landmark landscape elements of the city. This is conducive to environmental protection and promoting the vitality and diversity of urban spaces.

4.1.4. Surrounding value
Jinling Arsenal is located in the important cultural heritage gathering area in Nanjing, and the surrounding heritage types are rich. From the Western Zhou Dynasty (around 1000 BC) to modern times. The city, river, mountain, forest, pagoda, temple, and folk house are integrated with a time span of more than 3000 years. The historical information and cultural symbols of different periods in the region are overlapping and mixed, which constitute an important and unique urban cultural landscape. In the evolution of the regional space environment for more than 3000 years, the former site of Jinling Arsenal, as a cultural fragment of modern times (1840-the 1980s), together with the surrounding sites, constitutes a cultural core area full of personality and vitality in the south of Nanjing.

4.2. Principles for operation methods
Fully implementing appropriate policies, measures, and laws can ensure the complete protection and reuse of industrial heritage. These measures not only include sorting the documents, drawings, and archives for recording the changes of heritage but also help to deal with the relationship between heritage reuse and society, economy, investment, and management. The intangible cultural heritage and material environmental protection (ICOMOS 2011) are also taken into account. The conservation and reuse of the former site of Jinling Arsenal should be guided by the specific value, and “do not destroy the historical fabric” should be taken as the basic principle. Meanwhile, a protection planning system from the whole to the part should be established, through taking targeted technical measures from the maintenance of the overall historical image of the park to the protection and repair of each historical building. Full consideration should be given to the coordination among heritage development and urban environment, implanted new functions, and original construction technology and art.

4.3. Holistic space protection
As a goal of overall protection, multi-level display aims to achieve the continuation of the historical and cultural atmosphere and industrial landscape image
during the implementation process, incorporate the displayed content into the overall historical framework of the city, and highlight space characteristics of urban cultural diversity and identity (Bandarin and Oers 2012), as well as the new economic vitality. Not only are the cultural relic buildings protected and restored, but the built-up environment of the original lush greening and mountain terrain of the factory area are preserved as well, to keep the serenity and quietness of the area. In addition, the material heritages such as military weapons, rails, tanks, and production equipment are protected and exhibited in the factory area, and the intangible heritages such as factory songs, slogans, audio-visual materials reflecting the history and culture of the factory area are excavated and displayed (Figure 14).

The former site is integrated with the surrounding rich historical and cultural resources and urban space system, by opening closed walls, strengthening the formation of different entrances and squares, connecting the surrounding humanistic and ecological elements, combing the spatial structure system, and rationally organizing road traffic parking, etc.

Planning and design form three major functional orientations: "Military Industrial Culture Expo Park, Creative Office Gathering Zone and Quality Life New Landmark", trying to highlight the site memory while awakening the new vitality of the site, which makes it an important part of the "National Cultural Leisure Tourism Zone" in Nanjing.

4.4. Case study on techniques for protection and repair of architectural heritage

The protection and repair of heritage buildings requires a clear understanding of the causes of damage and decay and the necessary measures to be taken, especially the structural restoration. Compared with the general cultural relic buildings, these work are both objectives and means, because in the existing buildings of Jinling ordnance factory, the structural form and mechanical logic that we face are important parts of heritage significance. Therefore, surveying and mapping survey, characteristic analysis and structural safety appraisal of architectural cases in different periods and structural types have been carried out, and the multi-level value of heritage has been evaluated. On this basis, targeted measures are taken to carry out conservation and repairment.

4.4.1. Architectural heritages of brick wood structure in the Qing Dynasty

The Bearing systems of the main buildings of Qing Dynasty are brick – wood composite structure system. There are some problems, such as uneven settlement and deformation of brick foundation, weak wall cracks and seismic performance, unstable connection of

wooden house frame members and partial damage of external facade. The main protection and repair work include:

1. Brick foundation reinforcement: The reinforced concrete strip foundations are added on both sides of the original brick large footing foundations, which not only greatly improve the overall performance of the foundations, but also serve as the rooting parts of the wall reinforcements (Figure 15).
bearing reinforcement, so as to reduce the adverse effect of the cracks in the supporting walls.

(4) Reinforcement of wooden roof trusses: The connections between members of wooden roof trusses are strengthened to ensure the reliability of the joints. The connections between purlin and upper chord of roof trusses are strengthened, and a proper vertical support system is added, and the connections between the wooden roof trusses and the ring beams or walls are strengthened to ensure the overall stability of roof trusses (Figure 17).

Secondly, the overall architectural form is restored. Special repairs are carried out on the roof, exterior walls, doors and windows, interior walls and floors. To maintain the sense of historical vicissitudes of the buildings on the premise of ensuring safety, different repairing methods have been adopted for the exterior wall bricks: The wall bricks which are damaged, missing and weathered seriously (the sections of the blocks are weakened by more than 1/4) and which lose bearing capacity are customized and replaced according to the sizes and materials of the original wall bricks; for most of the wall bricks which are only partially damaged on the surface and have no loss of bearing capacity, the original bricks are retained; For the damaged and loose masonry mortar, the improved lime mortar is used for grouting and pointing reinforcement (Figure 18).

4.4.2. Architectural heritages of reinforced concrete structures in the Republic of China

For the architectural heritage in the Republic of China, in view of the problems such as insufficient durability and bearing capacity of a small amount of concrete foundations, the different degrees of carbonization of concrete beams and columns, and cracking of floor slabs, the main reinforcement and repair works include:

(1) Foundations reinforcement: The method of enlarging section is used to reinforce the independent foundations of concrete columns. The method of adding reinforced concrete strip foundation is used to reinforce the foundation with large footings of infill walls.

![Figure 15. Reinforcement of Foundation.](image1)

![Figure 16. Reinforcement of Wall.](image2)

![Figure 17. Partial Compression and Reinforcement of the Wall and the Overall Reinforcement of the Wooden Roof Truss.](image3)
(2) Reinforcement of concrete beams and columns: For the part where the carbonation depth of concrete is less than the thickness of the concrete cover according to the test results, the surface is coated with the permeable concrete durability protective coating. For the part where the carbonation depth of concrete is close to the thickness of concrete cover and where the steel bars are not corroded, the reinforcement is carried out by the method of full-wrapped carbon fiber cloth or wrapped steel plates, considering that the corrosion of the steel bars in the subsequent use may reduce the bearing capacity of the component to a certain extent. For the part where the concrete carbonation depth is greater than the thickness of the concrete cover and where the steel bars began to rust, the surface concrete carbonized layer is first removed, the rusted steel bars are subjected to rust removal treatment, the reinforcement bars are added depending on the situation and types of structures, and reinforcement is then carried out using polymer mortar or high-strength grouting materials.

(3) Reinforcement of concrete slabs: For partially damaged concrete slabs, a new 30 mm thick composite slab is added to the bottom of the original concrete slab by using reinforced polymer mortar repair technology to restore or even improve the bearing capacity of concrete slabs, while ensuring the durability and waterproofness of the concrete slabs.

Since the exterior image of the building during this period is mostly intact, the repair of the exterior of the building basically consists of the removal of additional part and reconstructions in the later period, restoration

Figure 18. The Large Machine Factory: (a) Before the Repair, (b) After the Repair.

Figure 19. The D4 Building in the Republic of China: (a) Before the Renovation, (b) After the Renovation.
of the original appearance of the building, and repair of local damaged parts (Figure 19).

4.5. New function

In China, most industrial heritages are mainly used as creative industrial parks, which are affected by the historical characteristics and types of heritages, local cultural resources and cultural policies of the government (Chen, Judd, and Hawken 2016). Nanjing’s profound culture and local government’s support for heritage transformation provide great advantages on the reuse of Jinling Arsenal. As mentioned above, on the basis of clearly expressing the historical characteristics of the heritage, new functions should be implanted in the adaptive reuse of Jinling Arsenal. Therefore, the strategy of “suited function, minimum intervention” in the design has been established: In terms of function setting, priority is given to the public function which is consistent with the history and value of the buildings, ensuring that the building is the least adversely affected and open to the public. For example, the large machine factory is set as the official headquarters of the parks, and the left, middle and right machine factories are set as the history exhibition halls of factories. For more buildings that function as

Table 2. Statistics on the Types of Enterprises that Moved in after Renovation and Utilization (2019).

| Case presentation | Types of new uses | Function | Quantity | Building number | Percentage |
|-------------------|-------------------|----------|----------|-----------------|------------|
| Cultural experience | Gallery, museums, teahouse, coins, sculpture, embroidery, bamboo art, etc. | 24 | B1, B2, B3, D5, D6, D7, E11, E7 | 15.1% |
| Research & Development of science and technology | Aviation, electronics, intelligent equipment, software, Internet, network information, etc. | 45 | A3, A9, A10, C1, C2, C4, D3, E8, E10, E13, E14, E16 | 28.3% |
| Creative design | Architecture, decoration, landscape, medium, animation, photography, wedding, etc. | 51 | A1, A2, A3, A4, A5, A6, A10, C1, C4, D3, E7, E8, E9, E10 | 32.1% |
| Commercial office | Investment management, consulting services, real estate, trade, etc. | 28 | A4, A7, A9, A10, B9, B10, C1, C4, D2, E8, E12, E15 | 17.6% |
| Business services | Hotel, catering, health care services, etc. | 11 | A3, B5, B7, C4, E6 | 6.9% |
regular creative offices, the necessary internal space transformation is carried out in the regeneration designs, adhering to the principles of authenticity, identifiability and reversibility. Indoor space is as open as possible to ensure the complete display of the structural systems such as beam columns and roof trusses. Lightweight, simple, reversible materials and formal language are used to perform the necessary vertical or horizontal spatial separation. Thereby, the revitalization and utilization of cultural relic buildings can be realized under the premise of complete protection and display.

According to the actual situation of the types of settled companies in 2019 (Table 2), there are currently 159 companies, in which creative design companies account for the highest proportion, and commercial sales are the least, but all belong to leisure businesses. Interestingly, all the new functions of the remains of Qing Dynasty are for cultural experience, and the specific functional types are all related to traditional culture, which further shows that the negotiation process between the historical characteristics and new functions of the heritage in this case is positive, and the unique late Qing military industrial heritage and traditional cultural attributes are compatible with each other. They are in a symbiotic relationship, defining a new dynamic space. At the same time, it can also be seen that such entrepreneurs or individuals are more willing to accept or even fall in love with the legacy of the past, and experience and explore their potential after possessing them.

5. Summary

A military heritage site, the former site of Jinling Arsenal, is a typical representative of the early China’s industrial revolution. It was built in the period of “Self-Strengthening Movement” with the guiding ideology of “Chinese essence and Western utility” in the late Qing Dynasty, and the period of the Republic of China with the warlordism and wars continued. These special backgrounds determine that Chinese industrial revolution was essentially different from the western industrial revolution led by systematic development of science and technology. The initial industrial revolution in China was based on the aspirations of national self-reliance, but a process of passively and selectively absorbing western technological civilization with an attachment to the feudal tradition system. These are reflected in the heritage of Jinling Arsenal, the architectural structure systems, facades and spatial forms have not copied those of the construction technologies under western industrial civilization, and they are not widely referenced in China’s later construction. And its attributes and essences show transitional, mixed, and non-systematic characteristics corresponding to a special historical period. These unique aspects record and reveal the political, social, and architectural-technical changes of modern China.

This study defines the value evaluation category of modern military-industrial heritage based on the background of the times, identity significance, architectural technology, and style. Moreover, it establishes a set of appropriate protection and reuse methods and strategies guided by value. This paper holds that critical thinking is important for the conservation and reuse of such heritage sites to consider the historical significance and material characteristics of heritage and how to maintain their vitality in the contemporary era. Different historical backgrounds decide heritages’ particular meanings, characteristics, concerns of reuse, and future development directions (Silva and Chapagain 2013). In our times, the heritage of the former site of Jinling Arsenal has come to representation of identity continuing the memory of the country, the city, and citizens. It is necessary to focus on the authentic protection and restoration of the built forms that could reflect the significance of heritage. The overall protection of the built environment includes the spatial layout, buildings, production equipment, greening landscapes, and other elements. Based on structural safety and service life inspection and appraisal, the targeted repair techniques are taken to maximally hold the original construction state for heritage buildings with different materials, structural forms, and spatial scales.

This study also clearly distinguishes the relevance between the meaning of heritage and new uses, and believes that it is necessary to establish a negotiation mechanism between heritage space and reuse. The given new functions cannot ignore the original formal features of showing the significance of heritage, a sustainable process of dialogue, and negotiation is formed between both of them by space and displaying features. In practice, it is indicated that the process of negotiation is a long-term and complex process of exploration, which is mainly manifested in two aspects. The first is that historical research and protection practices are phased, while the possession and reuse of heritage is a long-term process. As a result, related academic research and professional practice cannot guarantee the sustainable development of heritage conservation and adaptive reuse. For example, at present, most of the internal space of heritage buildings are renovated by the tenants. The architectural structures with special significance emphasized are ignored, and most people’s understanding of heritage only remains on the exterior facade of the heritage. The second is embodied in the development model and management system. Different from the four main development modes of China’s industrial heritage as a creative space summarized by Zielke and Waibel (2014), the former site of Jinling Arsenal adopts the mode of central enterprise leading investment construction and daily management and operation. The nature of central enterprise determines that it pursues low input and high yield, and it is not easy to obey the management
of local governments. Under this background, the heritage become over-commercialization, and it is largely traded as object of consumption by operators, resulting in the excessive density of part of the heritage spaces being occupied and used for a long time, which makes the heritage lose its right of self-expression. For example, the building E8 of the Republic of China used to be a two-story building with an area of 2806 square meters, but now it has been transformed into a three-story building, with a usable area of about 3813 square meters, and 19 enterprises have settled in it. Among them, the largest enterprise occupies an area of 801 square meters, and the smallest enterprise with 25 square meters. Too many scattered enterprises share a common heritage, which exacerbates unclear ownership and management confusion, and these problems are not conducive to the sustainability of heritage.

6. Conclusion

As an essential goal of heritage protection and adaptive reuse, sustainable development has not been fully implemented in the modern Chinese ordnance industry heritage renewal, which is due to a lack of both mechanism and platform to achieve effective negotiation among multiple subjects. Based on the analysis of the former site of Jinling Arsenal and its current situation, it is also crucial to use the creative industry park (the entire old arsenal site) as the regional scope to establish a heritage community (Crooke 2010), composed of academic experts, land-use planners, architects, local governments, operators, and users. As a kind of social organization composed of various related groups outside the local cultural relic department, the heritage community has more direct, efficient, and flexible advantages in dealing with problems facing heritage protection.

All members of the heritage community need to fully comply with and implement the basic guidelines, national policies, and regulations related to heritage protection as a consensus. This will ensure more effective conservation and reuse of industrial heritage as a common goal. To ensure the efficient promotion of the practice process, all members should closely consult and perform their respective duties to continually protect the heritage. In the process of specific practice, academic experts evaluate the value of heritage, with the right to interpret the heritage, and provide theoretical guidance for heritage protection through investigation and literature research. On the other hand, planners ensure that the industrial sites become an integral part of urban development through land function positioning, spatial system sorting, urban transportation, and infrastructure planning. Architects are responsible for specific practical work, choosing rational concepts and scientific technological methods to restore and protect different types and values of heritage (Wang 2009). Investors and users need to do a good job in the daily maintenance and operation management of the heritage. As the executor and supervisor of relevant policies and regulations, local management departments should supervise and control the individual behavior of investors and users. As the members of the heritage community, these target groups take the regular consultation meeting on heritage status assessment and protection as an essential institutional tool and are directly responsible for the protection practice and update of each heritage. The consensus formed at the meeting is the basis of each work and practice, and it is put on a record.

The former site of Jinling Arsenal is a typical representation of modern Chinese ordnance industry heritage. The experience of its conservation and reuse proves that the industrial heritage area is always in a relatively protected state, and almost every year, different degrees of protection and repair work to be done. Through the establishment of heritage community, the negotiation among members becomes the habitual mechanism that is helpful to realize the sustainable development of heritage. For the participating subjects, this can better ensure the corresponding responsibilities. For the heritage, the space itself can actively engage in dialogue with external interventions, showing tolerance and adaptation to different functions, as well as the continuity of heritage characteristics with time changing and the tension of heritage meaning in the face of complex environments.

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