Post-Industrial Redevelopment Site Design Reclamation in Shanghai, People's Republic of China

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***Abstract*—In the post-industrial era, many manufacturing sites were abandoned and languished. Site reconstruction and redevelopment has become an increasingly popular activity in engineering, urban planning, and design around the world. In Shanghai, many famous industrial heritage sites have been transformed into public facilities, but there are still many other abandoned industrial sites within the community. This study selects a post-industrial site in Shanghai, explores three different alternatives expressing different design concepts. The Friedman two-way analysis of variance by ranks evaluated the results between the three alternatives (traditional design, a green design, an industrial inheritance design) across 25 planning, design, engineering criteria. The analysis revealed that at least one treatment was significantly better than another treatment ($p \leq 0.05$). A multiple comparison indicated that the industrial inheritance alternative was significantly better ($p \leq 0.05$). This research can assist engineers, landscape architects, urban planners, architects, and others interested in assessing alternatives in industrial site reclamation.**

Keywords—environmental design, urban design, design process, site analysis, engineering research

I. Introduction

A large number of cities around the world are now entering the post-industrial era, with manufacturing factories being replaced by service industries, and abandoned sites turned into brownfields [1, 2]. Brownfields typically refer to sites contaminated by industry with more than 450,000 locations in the United States alone [3]. As many industrial age buildings and sites will be demolished or refurbished, the question is: how can one reuse or preserve these cultural heritages and rejuvenate them? The cultural renaissance emerged in the 1980s as a result of the transformation of the economic structure of Western Europe in the 1970s, which led to social and economic transformation, especially from the industrial economy to the post-industrial economy [4, 5]. Sharp and colleagues found that cultural strategies can promote cultural consumption and integrate cultural infrastructure such as theaters and museums to achieve economic recovery and urban uplifting [6]. This study focuses on the cultural heritage of redeveloping industrial sites. The transformation of the industrial economy into the post-industrial economy has resulted in many industrial sites losing their original value. However, for landscape architecture, these renovations have become popular topics. Scholars, concerned citizens, and governmental agencies are interested in discovering how to maximize the preservation of these former industrial sites and facilitating old cultural values to intersect and harmonize with the new cultural values. In addition, they are interested in approaches where the post-industrial landscape can be preserved and yet form a new type of landscape [7].

Wu suggested that it is inevitable for people and planners of many cities to reclaim old brownfields, because there is no better alternative plan, such as a plan to ingeniously transform those brownfields [7]. To find a solution, Wu's approach to design depends on the most complete integration of cultural and economic values. However, to expand cities, governments need more economic returns, which is why most industrial sites have been demolished [7]. Wu recommended to explore more sustainable development plans for the protection of heritage and residents' interests. Wu also recommended preserving cultural identity, protecting the original urban landscape, providing connections to local villages and the city center, creating new jobs for locals and new immigrants, and creating new green, multi-purpose public spaces [7].

Many factories have become obsolete through the elapse of time, and various problems have emerged, such as site pollution and the restrictions those factories impose on urban development. In the face of outdated industrial land, cities often answer by abandoning them, but such abandonment will bring negative economic, social and environmental effects to urban areas. Demolition and landfilling are the main methods to remove these leftover sites, but those treatment methods will cause many detrimental consequences, such as heavy metal pollution and other chemical pollution [8, 9]. In addition, as most of the debris is landfilled, it results in large amounts of carbon dioxide emissions and land pollution [10].

The post-industrial transformation aims to renovate and improve some abandoned factories and buildings from the old industrial period. The conversion of industrial heritage is a novel development concept for all cities in the world. Those industrial heritage are records of history, economic recovery and social development. Today, many manufacturing plants that have been abandoned are turned into green spaces and buildings for service industries. Reconstruction has become a trend in cities around the world [11].

A considerable part of the data shows that there is a huge potential for transforming construction material in the structures and infrastructure of industrial land, and some materials can be completely reused or recycled [12]. In addition, some building parts, which have been designed from the beginning to be easy to install and disassemble, will achieve better sustainable development in the future re-modification or improvement [13]. Therefore, by properly redesigning old industrial land, we can improve the old industrial land heritage redevelopment method. It can not only protect the environment and achieve sustainable development, but also provide better welfare to the community and offer residents aesthetic enjoyment and convenience in their daily life.

There is a prevalent belief that the industrial society has entered a period of rapid change since the 1960s. For instance, among one of those changes is the transformation of the focus of production – from product production to service production [4]. Since 1960, human beings have been in the post-industrial era for a long time, as generally recognized by the public. Post-industrial redevelopment has increasingly become an important factor in land-use planning and urban design, because it directly helps to determine natural resources consumption, especially non-renewable resources, and also helps to gradually develop renewable resources. At the same time, redevelopment will also coordinate economic development and environmental elements with the people [14]. The original post-industrial landscape is functionally and materially obsolete and, in many cases, decaying. Although historically significant, these sites are often not widely regarded as valuable contributors to our heritage. However, these landscapes still exist, and we cannot deny that they are indeed culturally significant [15].

Protecting the industrial sites as a cultural heritage is very important. In the Middle Ages, nature did not exist as a theme. With the beginning of the Age of Enlightenment, people began to create and become independent thinkers. The German philosopher J. Johann Gotfried Herder saw the continuity of human progress as a goal of history. In his opinion, every chapter of history can be regarded as a cultural unit [16]. The land of the old industry is a symbol of the industrial age, and the construction land itself has a very strong historical and cultural presence. Thus, with the regeneration of abandoned industrial land and the development of industrial heritage tourism, the post-industrial landscape enhances people's memory of industrial civilization, improves the relationship between site use and local people, and is conducive to the reform of declining industries [17]. In spite of the pollution brought about by industrialization, the advent of industrialization was a milestone in human history. It has brought about a series of lifestyles that people are familiar with now, such as urbanization. [18]. If a cultural heritage is linked to the surrounding culture and environment through transformation, then it can be preserved. Thus, this proposed study will benefit not only the urban planner but also the whole urban society.

In fact, industrial heritage can also be considered as cultural heritage. With the development of technology, most architectural forms with industrial characteristics will no longer exist. Preserving some industrial elements during land transformation is a commemoration of human history. It will remind people how human beings gradually change the world through machines, and to encourage people to make future development. Thus, the results of this study may have a long-term impact on the life of people living in urban areas.

The purpose of this research proposal is as follows: 1) to analyze how to preserve old industrial sites as a cultural heritage, 2) to maximize the preservation of former industrial sites which is a part of history, and 3) to identify the meaning of culture heritage to the surrounding society by strengthening the relationship between the community and the industrial sites. This study collected different elements that affect the post-industry redevelopment process, try to re-design a normal abandoned factory in Shanghai, and discuss what kind of design is more effective and beneficial for both the redevelopment and local citizens. Finally, as people tend to easily ignore cultural heritage in some industry sites, there is a need to determine how to protect and transform the sites in a landscape way and re-express the cultural heritage with a new vitality.

II. Literature Review

A. *Redevelopment Issues*

In the post-industrial era, retaining original industrial land is not a simple issue. It requires the involvement of local governments and capital operations. Therefore, a large amount of abandoned industrial land during this period was abandoned and abolished [15, 19]. Demolition of building structures generates a large amount of material, which in most countries causes a lot of waste. In the United States, demolition waste accounts for 92% of the total construction and demolition (C & D) waste of 136 million tons per year, and about 125 million tons of demolition is sent to the landfill [20].

The commencement of this redevelopment process causes some issues in society. In some studies, economic reasons have been shown as an important part of the issues regarding the allocation of responsibilities, which is often identified to be one of the main factors that lead to funds moving away from industrial transformation [7, 21]. Also in another paper, Gao and colleagues showed issues about allocation of responsibilities in the post-industrial site, and this study has proved that there are disputes between the original land users and the landowners over the allocation of reconstruction costs and the distribution of potential profits, and neither is the government willing to bear the consequences of the economic loss incurred by the transformation [22].

Some redevelopment factors, including location, local government support, and the allocation of investment costs, suggest that there is also asymmetry between rural and urban areas. Because of the location of major transportation infrastructure, the previous functions of the brownfields and threats to the environment are factors that the government is

ISSN: 2692-5079

considering in rebuilding industrial land. The analysis of the article did not find a significant impact of population density on brownfield redevelopment, but those brownfields are more likely to be located in cities with higher development potential, so these factors limit the possibility of redevelopment [23]. Additionally, the inherent high costs in remediation often require large amounts of financial investment to reduce pollution to acceptable levels [18]. One solution may be to rebuild the areas and make them more welcomed by the society, but these previous efforts did not suggest that specifically.

While people who rebuild industrial lands are primarily driven by economic reasons, the value of heritage conservation and community development is also considered as another consideration. In some medium-sized cities like Spokane in Washington, due to the significant reduction in government involvement, individual private investors have undertaken contemporary renewal projects on a small scale, such as building parking lots, new buildings for commercial use, and tourist parks around historical buildings [24]. This makes it possible to retain industrial heritage land as a cultural heritage. In medium-sized cities like Spokane, non-financial needs are particularly strong, and developers must have strong links with the community. The reason is that, if the developer and the community are not well connected, the following will happen: the public square becomes barren and unattractive, and many public housing projects will exacerbate social ills. Therefore, design decisions and residents' attitudes are especially important in this situation.

B. Design Method and Resident Attitude

Specific design principles and methods may practically influence and guide redevelopment in reality. In a survey based on a review of 346 case studies worldwide and an in-depth study of six post-industrial case studies, Loures and colleagues demonstrated the importance of identifying a set of plans and successful use of design principles to rebuild the project that creates the base for post-industrial redeveloping, thus revealing the importance of having a method first [25]. They considered post-industry land as having a high heritage value, recognizing that art, history, and creativity are still key elements of overall design [25].

More specifically, the redevelopment of the park is closely related with landscape design. Loures and colleagues suggested a few methods based on the Millennium Park project in Chicago [25]. For example, by creating a space where people can enjoy their own space and have an intimate relationship with nature and culture, Millennium Park has cultivated a considerable sense of belonging among Chicago citizens. In fact, it’s a great example of realizing a unique public-private sense of belonging, not only to capture the attention of private donors, but also to contribute to the construction of parks, especially with the artistic and architectural features. The general public regards the park as one of the reasons for the destination of locals and tourists.

Resident preferences are one of the factors that determine how to rebuild the industrial site. In Navratil’s study, the overall attitude of residents to brownfield was positive, and the transformation of industrial land into green land was recognized by some residents [26]. Even unregulated urban green spaces can be highly valued by residents, who realize that this green infrastructure can benefit to avoid the urban heat island effects by cooling down the city. However, it is not always accepted by the public. Surprisingly, people living in the center of city have less interest in rebuilding public spaces for exercise and relaxation. However, in the suburbs, there is a high level of interest in turning brown areas into recreational places. It may reflect the lack of awareness of the downtown area service and residential functions [26]. Residents may have a preference for multi-functional areas and the greening of a post-industrial space may not be sufficient [27]. As the relationship between investors and the public is not well-connected, the rebuilders will easily fail with their project. When investors are not required under certain policies to invest through the local governments, those investors have no attachment to the local environment, so rebuilding the environment is purely a way to make money -- but it turned out that they failed to achieve a profit [24]. This suggests that disseminating more information about the reconstruction among local community and increasing the link between investors and the locals may promote the reconstruction of industrial land in medium-sized cities [24] However, there are still problems left unsolved by the above studies: What are the appropriate strategies for the industrial landscape redevelopment project, and what kind of landscape creative value and elements should the industrial land use to obtain the residents’ support?

C. Differences Between Designer and Local Citizen Perceptions

As described in Loures’ study, even if the importance of post-industrial land transformation is increasingly recognized, the benefits and obstacles of post-industrial reconstruction are difficult to define [18]. An appropriate strategy for industrial landscape redevelopment projects is to identify important obstacles and benefits [18]. Analyzing the different perceptions between public and experts, which is very important as the perceptions of designers and the public can be quite different [28]. In addition, the perceptions and expectations of respondents can be extensive and diverse [29]. Planning and landscape redevelopment activities have become more than just the professional visions of planners and designers [2].

Loures discussed a different understanding of the interests and barriers of post-industrial redevelopment between the public and experts, proposing that designers tend to focus primarily on aesthetics, placing other major goals of society in an unimportant position [18]. Post-industrial redevelopment must be seen as one the of several components in the broader context of urban planning and economic development, which shows the difference between new uses in the post-regeneration industrial landscape. ln Norrköping, Sweden, it was found that important cultural heritage values are ignored in order to adapt the landscape to new uses [30]. Cultural heritage can be in conflict with many stakeholders in redevelopment projects.

D. Deconstruction and Recycled Materials in Landscape Architecture

The most important problem arising from the above industrial transformation is the economic issues, and design for deconstruction is an emerging concept, a topic that has become popular recently. It draws ideas based on the design field in the consumer goods industry for disassembly, reuse, remanufacturing and recycling. It is usually defined as the recycling of components and materials from waste land for reuse and remanufacturing. Its overall goal is to improve resource and economic efficiency and reduce the impact of pollution in building alterations and eventual demolition [13]. The data show that the role of deconstruction can reduce waste and debris in the house. Demolition can reduce construction site waste by 50-70%, which may save resources and reduce emissions. The material recovered in the deconstruction project reduces the demand for raw material collection and reduces demand for long-distance transportation materials, as older buildings can provide materials for the renovation of historic buildings, or to protect them. In addition, the rate of waste removal from landfills is increased. There has also been a potential reuse of building components, and improvement in local and global environmental protection. [20]. The most important benefit of deconstruction is that it is often more profitable than simple demolition [31].

The Natural Gas Plant Park in Seattle, Washington, was one of the earliest well-known reclaimed post-industrial sites [2]. It expresses a method very similar to deconstruction in the concept of domicology [32]. In the view of landscape architects, the adaptive reuse of abandoned landscapes can not only improve contaminated land, but also transform it into a public service. Although both officials and citizens demanded the removal of the remains of the industrial plant, the designer succeeded in retaining the components of the industrial plant. These parts were not simply demolished but were given a new aesthetic and landscape mission through reuse. The parts of the industrial land that seem to have to be demolished are retained through the landscape. By preserving these structures, not only can history be retained as part of local memory, many economic problems have also been solved, as the demolition is replaced by the retention of a large part of the park 's revenue sources and new job opportunities created [1].

E. Current Metrics

Over the last decade the comprehensive metrics of environmental variables in landscape architecture have been advanced by the Landscape Architecture Foundation (LAF). In the LAF guide book, different metrics including environmental economy and society are listed in detail [33]. Since at least the mid-1980s, site design proposals and alternatives can be evaluated with various metrics and has greatly advanced [34, 35]. With a focus on sustainable development, one researcher in an early study selected rainwater, adaptability of wild animals and plants, and energy use as assessment indicators of the landscape performance [36].

On the other hand, due to the particularity of industrial land, the impact of construction on the environment should also warrant attention. A study shows that the impact of construction on the environment can be reflected in many indicators, including but not limited to construction and demolition waste, dust, impact of pollution, noise and vibration, other metrics such as the impact on wildlife and natural characteristics, the pollution of surface and groundwater, and other metrics [37]. At the same time, the research also noted that the indicators in the construction will be the destruction of vegetation, visual impact, noise, increase in vehicle flow and parking. The reduction of space and the destruction of public space are also issues that can be analyzed [37]. Thus, it is necessary to comprehensively consider the construction, structure, environment, society, economy and other indicators to effectively analyze the reliability and prospects of the industrial transformation design.

F. Friedman Methodology

Friedman methodology is a common way to detect differences in data. It is used to detect differences in treatments of multiple test attempts. Milton Friedman noted in his papers the use of ranks can increase the accuracy of data, involving statistical data collection and analysis projects, is to study the factors of variable changes [38, 39]. Before that time, statistical tools were mainly used for analysis of variance, and the data was often sufficiently extensive. This technical approach is not effective in any other way. Friedman suggested that by arranging each group of values of variables in order of magnitude, such as arranging them as 1, 2, …, and using these levels to replace the original quantitative values, the difficulties caused by extensive data can be avoided. In the paper, Friedman tried to provide a significance test for data that contains less than six groups of levels and the number of levels in each group is small or medium. The results are effective [40]. At this point in time, the Friedman methodology is a common and effective way to detect the difference of data. First, a wide range of data is effectively arranged and then the difference between several different treatments is detected through this methodology. In the field of design and planning, Friedman methodology solves the difficulty of different variables that are difficult to be assessed together, and it has been proven to be efficient and successful in the field involved [34, 40]. The following text describes several applications of the Friedman methodology in planning and design.

G. Roof Garden Example

The Friedman methodology was applied to study green roof design alternatives [41]. The location of the research is in the Sylvester Brooms Empowerment Village in Flint, Michigan. A total of five design schemes have been developed for the roof of the house. The site location -- Flint, Michigan, is the seventh most densely populated city in Michigan. It is an open house, now with a history of nearly 100 years. The building has a total of four roofs [41]. The five designs mainly include conventional, self-design, extensive, semi-intensive, and intensive. There are about 36 variables such as accessibility, plant and various

ISSN: 2692-5079

functions in the assessment. The study found statistical differences between some treatments.

H. Biospheric Landscapes

The use of Friedman methodology can distinguish between boispheric environments. In one study, a granite quarry in West-central Minnesota was analyzed and studied to find a suitable post-mining land use plan [42]. Because the quarry is adjacent to the Federal Big Rock Wildlife Sanctuary, the main land use after mining is wildlife habitat. The article has studied three main habitat treatment methods [42]. The study compared existing site conditions, a naturalization alternative without wildlife planning, and an alternative to create landscapes for nine wild animals. The article analyzes the data of nine wild animal and plants groups, with each plant and animal community having its corresponding comprehensive value of habitat. The ranking of each flora and fauna in the three alternatives are presented with numerical arrangement and are statistically assessed.

I. Earthquake Resilience

The Friedman methodology can also be applied to earthquake mitigation alternatives. In a study, researchers assessed environmental safety issues by investigating various landscapes related to the Wenchuan earthquake in China [43, 44]. There are three different landscape treatment methods through seven variables, including the height of the building, the space between the buildings, whether the building construction area is related to the flooding area, and the choice of escape route. Through Friedman methodology, the study reveal which alternatives were significantly more effective.

J. Railway Station Design

In a study on railway station design, the Friedman methodology was applied to assess design alternatives [45]. In a study, the researchers chose a station in East Lansing, Michigan, in order to study people's perception of location in an unknown environment [45]. The researchers conceived a total of five design alternatives and examined the train station from the window of the train. The final test showed that there are significant differences between all design methods ($p \leq 0.05$).

K. Housing Design

The Friedman methodology has also been proved to be useful in housing design. A study shows that the housing design is linked to healthy housing [46]. This research was conducted through a list of fourteen variables, including sound, touch, sight, smell, and air quality. These fourteen variables are used to evaluate the residential health of the entire indoor environment, and then the results of each housing style are obtained through different calculation methods, and the rankings corresponding to the fourteen variables are given through these results. The advantage of Friedman methodology is to rank various variables first, avoiding the incomparability of a large number of variable data. The final result shows that there was a significantly better alternative amongst the housing types ($p \leq 0.05$).

In literature review revealed that the Friedman methodology is helpful in assessing planning and design treatments. Therefore, it can be widely used in the field of design and planning and combined with the evolving application of landscape metrics [40, 47].

L. Research Plan and Intent

The study reported in this article selects an old industrial land site for design transformation and create different designs with different emphases. The Friedman methodology will be used to assess design alternatives.

III. Study Area and Methodology

The investigation developed is based on three design scenarios: the traditional renovation design, green environment design, and industrial heritage design. The main purpose is to transform an ordinary old food factory into a community resource by applying planning and design methods.

A. Study Area

According to statistics, Shanghai has a total of about 40 million square meters of old factories, some of which have been built for nearly a hundred years, and some of which are representatives of the Chinese national industry. In the report, not only the once excellent industrial buildings have changed from idle and abandoned to being protected nowadays, but some of common industrial buildings are also re-emphasizing their value in terms of history, culture, urban landscape and sustainable development through transformation and improvement [47, 48].

However, there are still many of the post-industry sites abandoned. What' is more, these factories are still polluting the surrounding environment. With the expansion of residential areas, local residents have begun to complain about abandoned factories, hoping to get more urban life experience. These abandoned factories urgently need a transformation plan to benefit the residents. Ever since Shanghai has carried out industrial heritage protection and redevelopment projects, a great number of industrial heritage buildings have been protected. With a lot of good examples, these remodeled factories are being well known and understood. But it also comes with the second question: excellent examples bring blind followers, leading to over-simplification of usage types. For instance, more than half of cases in Shanghai are transforming industrial sites into creative industrial parks [49]. However, having too many creative industrial parks is also a great waste of resources. These creative parks have specific targeted groups, artists and young entrepreneurs, which cannot form a coordinated relationship with locals.

B. Location of the Study Area

The site (See Fig. 1) is located by the Puhuitang River in Xuhui District, Shanghai, covering an area of approximately 1.8 acres (7400 square meters). It used to be the food processing plant of Shanghai Wanyouquan Food Company. To the west and south are Qinzhou Road and Huashi Road respectively, to the east is a river, and to the north is a traditional residential area. The entire selected area includes a production building, a flour workshop, a comprehensive building, a pump room and a boiler room.

C. Existing Context of the Study Area Location of the Study Area

The old food factory is located near the center of the city, surrounded by many famous hospitals and city shopping centers (See Fig. 2). Undoubtedly, there is very convenient transportation. First, there are more than a dozen bus stops brought by several bus lines around the entire station. Secondly, there are five subway lines. Although the stations are at a certain distance from the study area, they are also within walking distance. The surrounding area is mainly residential. There is a large city shopping mall in the north and south, and it is also close to a stadium. In addition, there are quite a wealth of educational resources in the surrounding area. From primary school to university, there are more than a dozen schools of various sizes, but the green area of the city is relatively less and there are only 4 public parks. In terms of road traffic, it is close to the inner road and Humin elevated Rd. The only two roads that directly contact the study area are Qinzhou Road and Huashi Road.

Fig.1. Location and geographic map of existing site (P. R. of China, Shanghai, Xihui District, site).

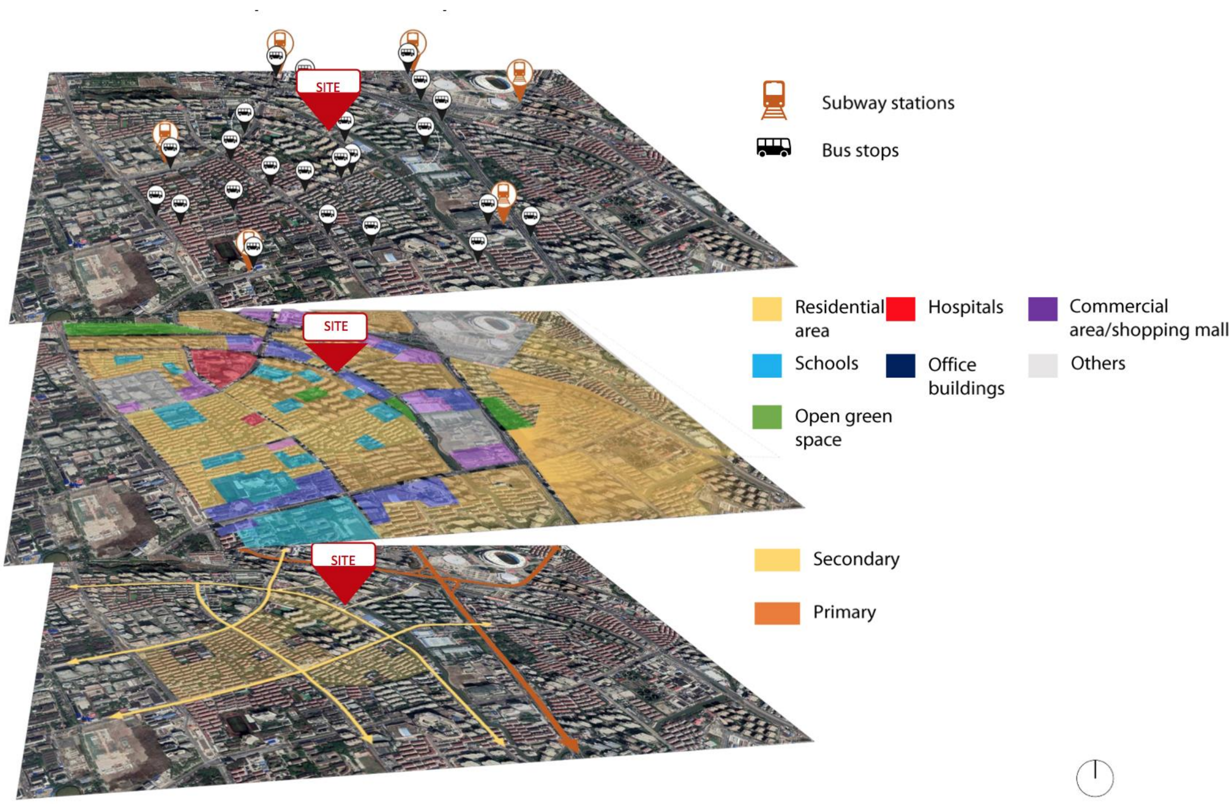

Fig. 2. Surrounding area map (Copyright ©2020 Zhixiang Zhang all rights reserved and used with permission).

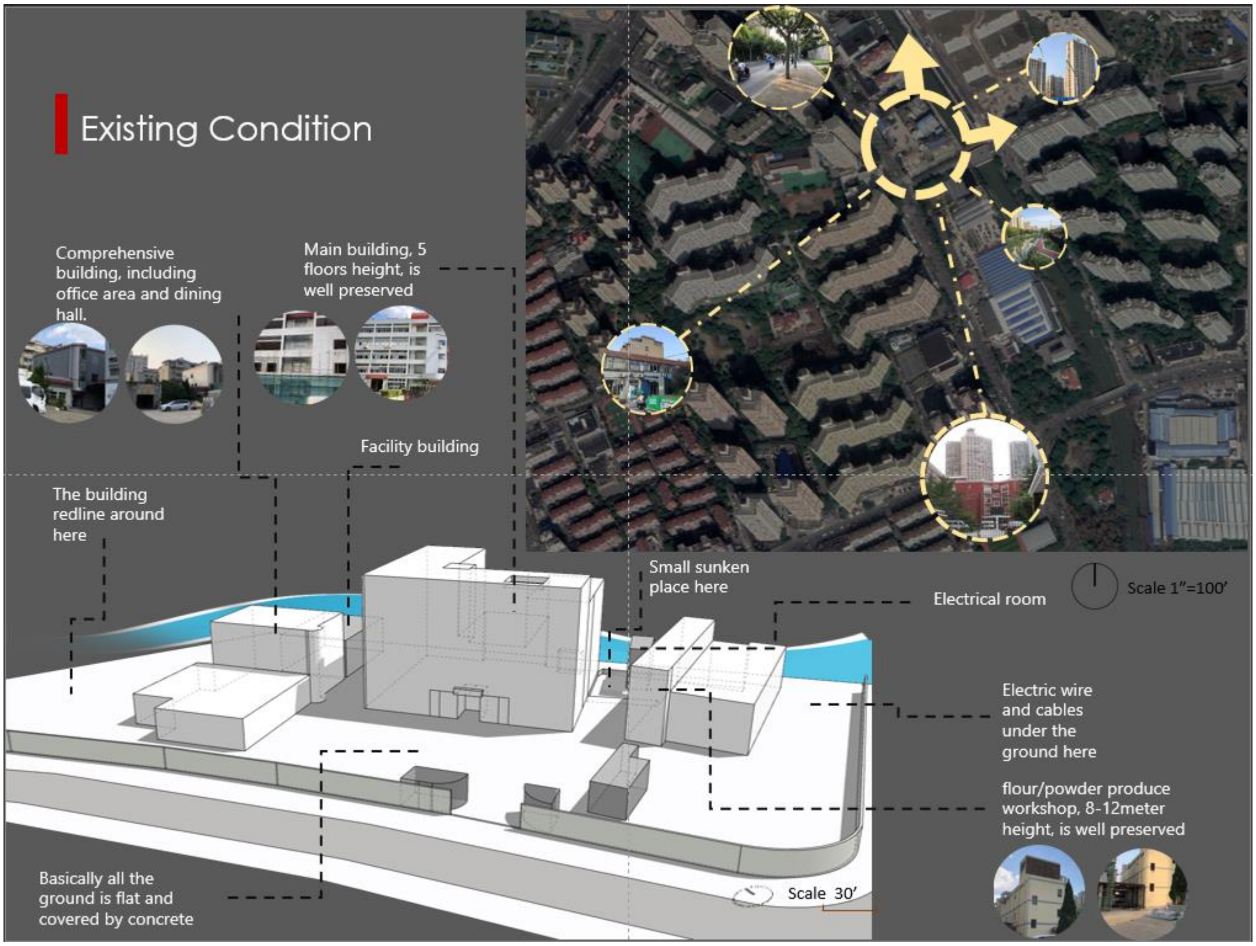

Fig. 3. Existing conditions (Copyright ©2020 Zhixiang Zhang all rights reserved, used with permission).

As can be seen from Fig. 3, since the site was once used as a food processing plant, a large area of the paving surface is made of concrete. The main building (the largest one in the picture) is the production building, with a total of five floors, each with an area of approximately 14,000 square feet (1300 square meters), and the building on the north side is a comprehensive building. The first floor was used for warehouses, the second floor was used for restaurants, and the third floor was used for meeting rooms. The first floor is approximately 8,600 square feet (800 square meters), and the second and third floors are approximately 3,500 square feet (330 square meters). To the south is the flour production workshop, with a total of three floors, but the third floor only has a small area, and the remaining two floors occupy an area of about 8,000 square feet (730 square meters). Except for the main three buildings, there are other small buildings such as power distribution room, garbage room, guard room, and a boiler room

Fig. 3 includes illustrating surrounding environment. The surrounding roads are typical traditional roads in Shanghai: each road contains two-way single-lane roads equipped with non-motorized lanes, well-planted street plants, the very narrow sidewalks about less than 6 feet (less than 2 meters), and also a 5 foot (1.5 meters) wide green belt. The north and west are mainly old-fashioned traditional small apartment houses, and the east are new high-rise apartment buildings under construction. There is a middle school close to the south, and the government next to the river is building a new green fitness trail and running track.

D. Design Process: Analysis of the Study Area

Compared with traditional industrial land, the study area has several special features (Fig. 4). First, because the geographical environment is relatively close to the city center, on the one hand it brings a lot of convenience, but conversely, the design needs to consider more aspects. Second, since the predecessor was a food factory, compared with the transformation of metal and chemical industry land, there are fewer concerns about hazardous substances and toxic waste from factories. Finally, due to the surrounding existing environment and some newly built projects, it is a challenge to integrate the study area into the surrounding environment.

In terms of environment, first of all, one should consider traditional streets. On the positive side, it brings a good street landscape. The long-standing plane trees provide a pleasant shade, and the dual-phase single-lane road restricts traffic volume. On the other hand, there are also some drawbacks, such as the sidewalks for pedestrians are too narrow, the green landscape is too simple and so on. Secondly, the surrounding areas are mainly residential areas and a large number of schools, which provides population resources and very complete infrastructure. For example, the transportation system has almost been fully covered, so that there is almost no need to consider how to reach the study area when designing. In addition, hospitals, shopping centers and other facilities necessary for daily life are within walking distance.

Second, one should also consider the limitations of the site. As mentioned above, because of the uniqueness of the food processing plant, the existence of hazardous substances should almost never be considered. The entire site provides a coveted start to industrial transformation. It is almost all covered by a cement surface, it brings an almost flat ground and an environment without soil. With several major cement buildings, the entire space is almost a gray space filled with cement. How to transform and protect this memory is what the design needs more time to consider.

Finally, one should consider whether the existing street shortcomings can be changed. In addition, the new waterfront runway, etc., combined with the development and transformation of industrial land, also need to be considered in the design.

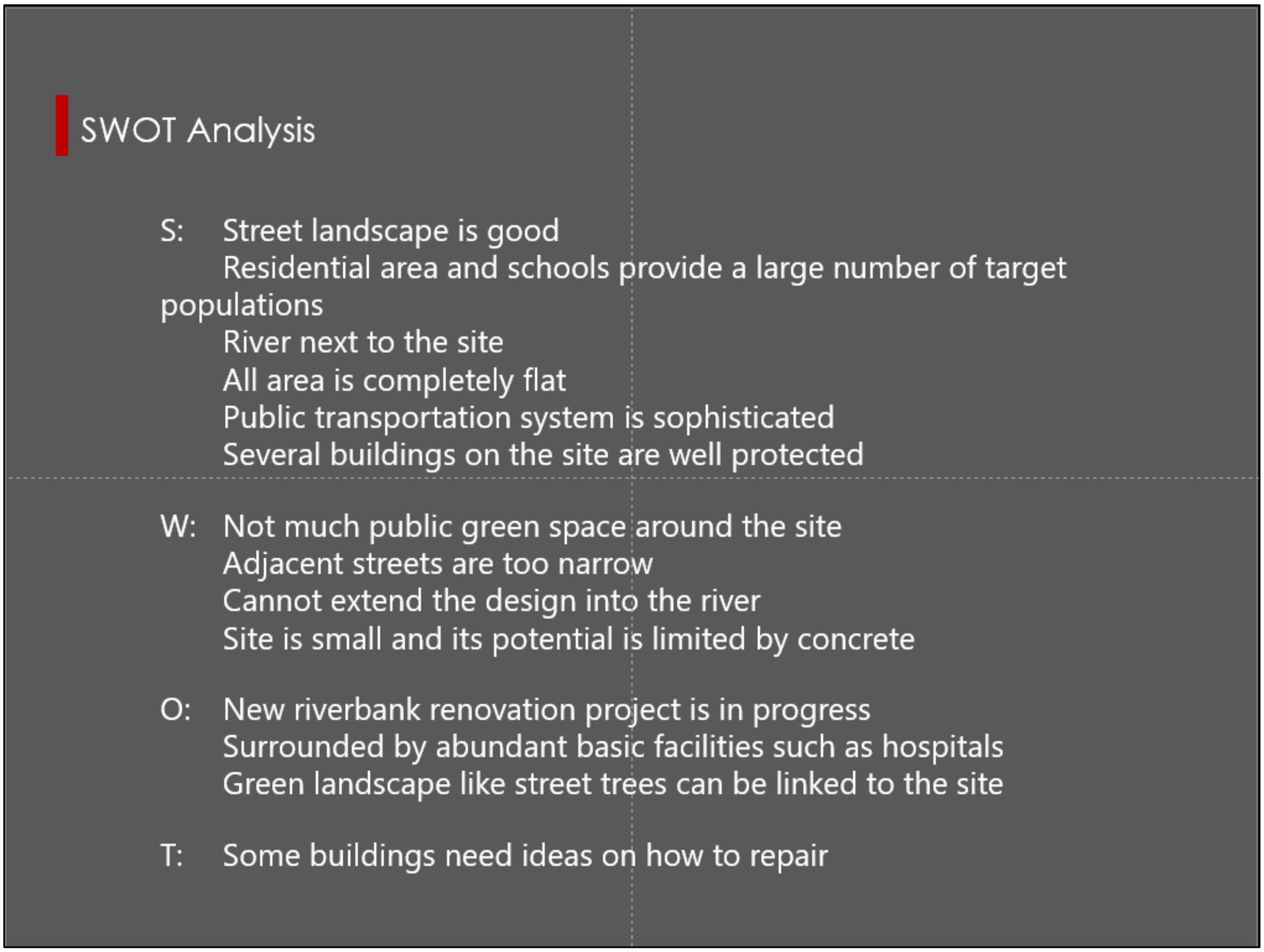

Fig. 4. SWOT (Strengths, Weaknesses, Opportunities, and Threats) Analysis (Copyright ©2020 Zhixiang Zhang all rights reserved, use with permission).

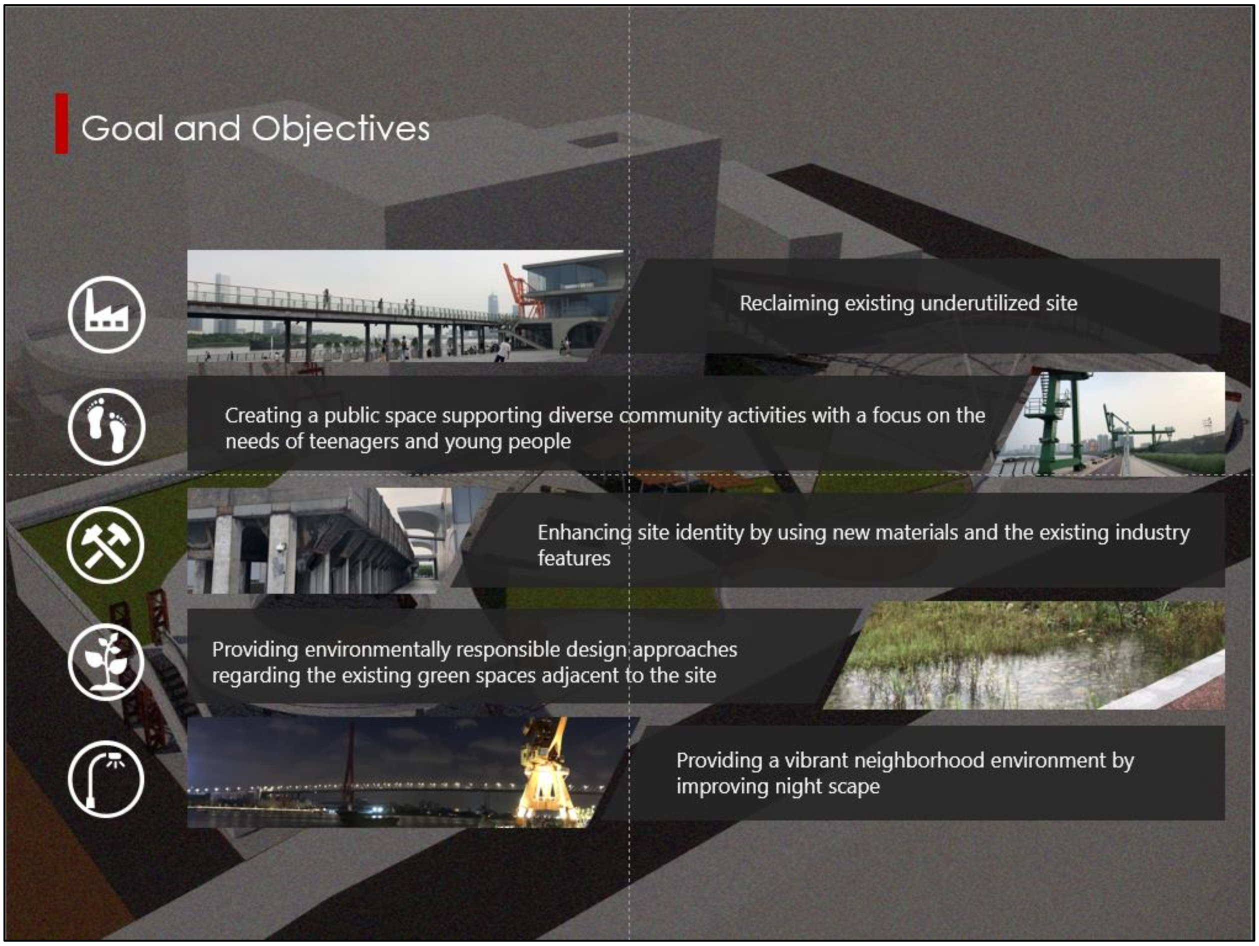

Figure 5 Design goals and Objectives (Copyright ©2020 Zhixiang Zhang all rights reserved with permission)

E. Design Process: Goals and Objectives

On the basis of the existing site environment and on-site analysis, there are five main goals and Objectives (See Fig. 5). The first goal is to reclaim existing structures and buildings. The site, especially the three main buildings, will be properly preserved and remodeled. This study mainly studies how to obtain maximum benefits and meet the surrounding needs through design methods in industrial transformation. It is necessary to maintain the main form instead of completely demolishing and then rebuilding. This can effectively reduce the shortage of material and manpower.

The second goal is to make places attractive to multi-generations including children and teenagers. Through analyzing and investigating the surrounding environment, the people that are the most likely to visit the study area are ordinary residents and youth groups represented by students. Therefore, catering to the interests of ordinary residents and students will greatly increase the success rate and satisfaction rate of site transformation.

The third goal is to use recycling materials and keep senses of belonging with the city. As analyzed in the previous literature survey, the biggest difference between industrial heritage transformation and general land use is that industrial heritage has many unique signs, such as production machinery, etc., which gives the site a uniqueness and offers the residents of surrounding cities a record of memory. Using more signs left over from industrial heritage not only adds some special marks to the site, but also gives residents a special sense of belonging.

The fourth goal is to be environmental-friendly. To promote sustainable development, the final design considers environmentally responsible design, and adopts environmentally sensitive design practices, such as rain gardens and permeable paving. It not only improves the site environment but also provides a livable environment for the next generation.

The fifth goal is to create a vibrant night scene by using lighting. Because the environment is close to the city center, when night falls, the venue should not be closed but should provide beautiful night scenes to bring enjoyment and convenience to residents and tourists who need activities at night.

F. Design Process: Three Different Design

With the support of analysis and design goals, I created three different designs in total. First, a green environmental design for environmental sustainability was chosen. Second, the traditional transformation design for activity areas and buildings was selected. Third, a design focusing on industrial heritage was also selected for design development.

G. Green Environment Design

The green environment design, in Fig. 6, mainly focuses on more sustainable development, such as more trees and shrubs, and more walkable areas. The area on the west side close to the street was transformed into a square with the only concrete paved surface. It is mainly responsible for becoming a main entrance and extending the function of the street. The main building retains two seats and hardly changes. It mainly undertakes some indoor activities and catering projects. The design focus is mainly on the south, and the entire south has been transformed into a large children's garden and walkable grass area. The production building is surrounded by a large flower bed that can be planted with flowers of different seasons, and can also be used as a rain garden when necessary. The height difference between the entrance of the building and the square of the site is connected by a wooden bridge. There is an iconic reflecting pool between the two buildings, surrounded by a walkable green area, which serves as a middle zone connecting several important areas. Except for the concrete plaza and green grass design at the entrance, the rest areas are covered with plastic to protect the youth and prevent accidents such as falls.

There are several areas that can be changed in the southern children's garden. The water pool can be used as a rain garden or children's play area under special circumstances. All paving can be mixed with steel or concrete pattern strips to enhance the industry identity of the site. Secondly, the designed reflector can be installed in the paving strip, and some outdoor tables and chairs are provided on the side of the flower bed for residents to use and rest. The northernmost design area is mainly for vehicles, including the underground parking lot entrance and temporary parking sites to facilitate the necessary parking needs of tourists and staff, and is separated by some trees and shrubs.

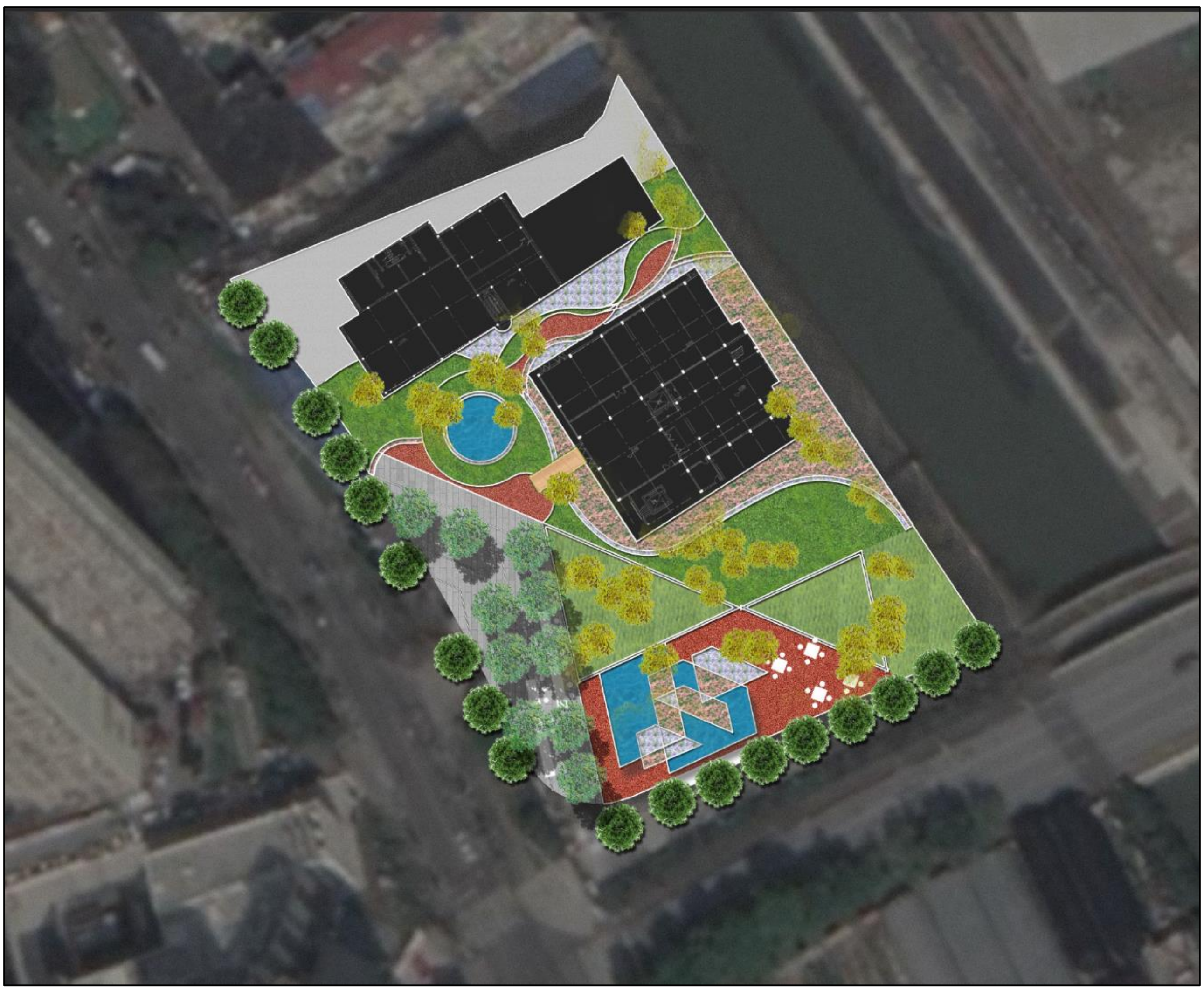

Fig. 6 Master plan of green environmental design (Copyright ©2020 Zhixiang Zhang all rights reserved, use with permission).

ISSN: 2692-5079

H. Green Environment Design

In Fig. 7, the image illustrates the traditional renovation design. The main idea is to focus on the design of the interior renovation, expanding and extending the three main buildings and connecting them with sky bridges to make them into a whole. The key point is that the transformation design can have the largest possible activity space, including but not limited to, canteens, classrooms, skating rinks, indoor badminton courts, table tennis courts, basketball courts and other indoor activity facilities. It will provide a leisure and sports place for nearby residents and teenagers.

On the basis of having the largest space, the remaining space can transform the original street environment by emphasizing the trees on the street, widening the width of the street, and making the entire housing area more open to the community. Designing a rest place surrounded by greenery in the priority inner courtyard space can provide some necessary services including charging and drinking, which not only provides space for resident residents, but also provides convenience for tourists. In addition, the north and south sides are changed to asphalt roadsides to facilitate vehicles entering, staying and leaving

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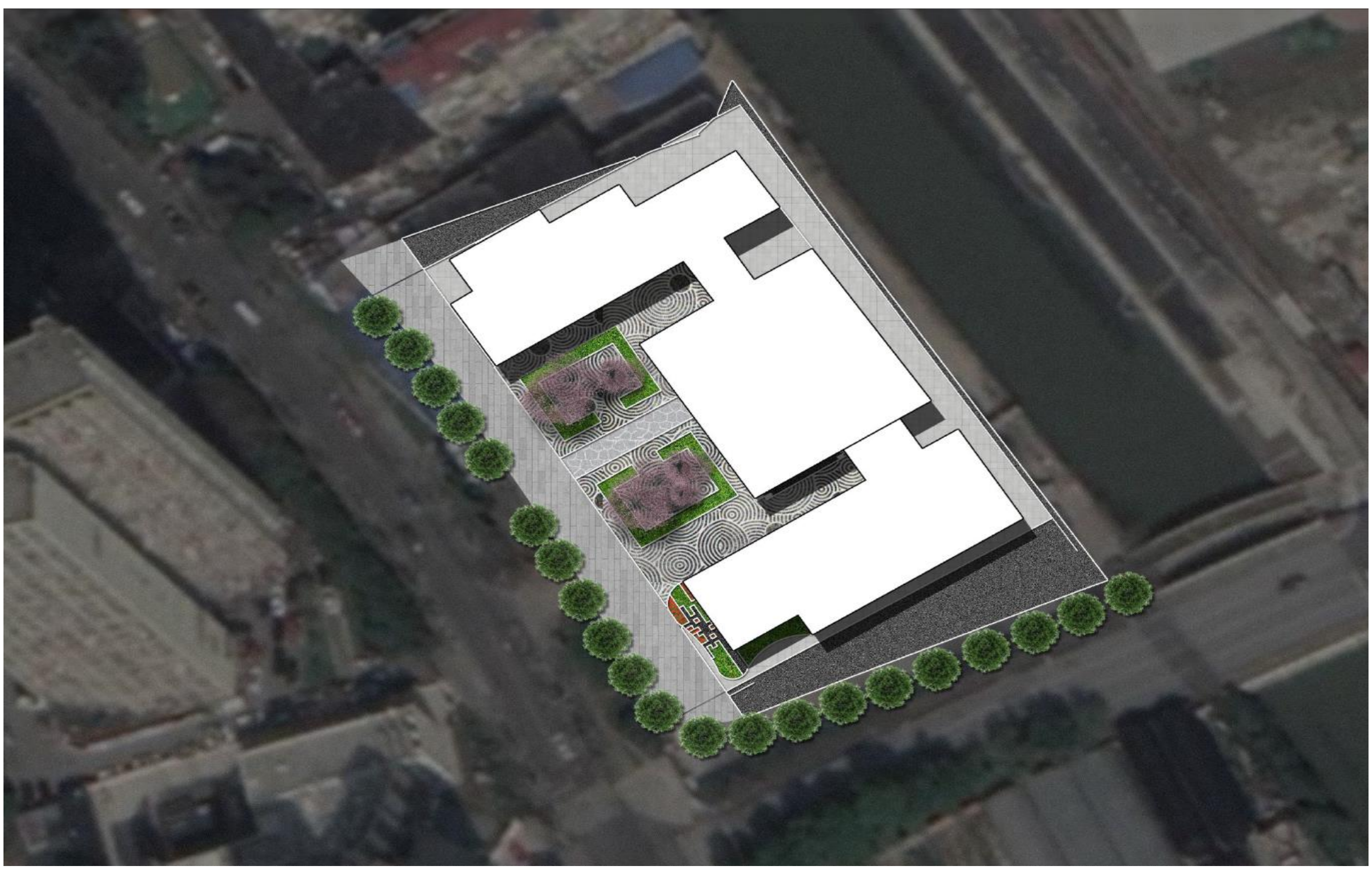

Fig. 7. Master plan of Traditional renovation design (Copyright ©2020 Zhixiang Zhang all rights reserved, use with permission).

I. Industrian Inheritance Design

For the industrial inheritance alternative (See Fig. 8, Fig. 9, Fig. 10), the whole design concept is to retain as many industrial elements as possible. Therefore, the three main buildings have been preserved and remodeled. The production building has minimal changes, mainly reflected in the addition of an open-air platform outside the third floor to connect to the complex. Secondly, the wall of the building is wrapped with a new wooden wall. The main function of the building is to carry out various indoor activities. Half of the complex has been removed and used as the entrance to a small parking lot and an underground parking lot. The roof design was added and transformed into a roof garden, which was connected to the production building by an overhead bridge.

The central part of the roof was hollowed out into a circle, and large trees were planted on the first floor to form a rich layering. The reconstruction of the comprehensive building is mainly used for the combination of grocery supermarket and canteen to provide daily necessities and food. As the heaviest but difficult-to-reuse structure of the industrial element, the workshop was also retained. The main outer wall was opened up, the concrete post was retained, and it was transformed into a facility for small outdoor sports and entertainment. The open space in the south has been transformed into a sunken square. The transformed square can host some small outdoor performances and light shows. In addition, a fountain installation has been opened up, and combined with the rain garden-like creek connecting the entire site to form a rich water resource landscape.

The entire site has also been expanded with hills of varying heights to attract young people to enjoy outdoor sports. In terms of landscape, a large number of waste steel and concrete leftover from the site are used as landscape sculptures, including flower beds with aerial steel frame structure, tables and chairs made of concrete and so on.

Fig. 8. Master plan of Industrial inheritance design (Copyright ©2020 Zhixiang Zhang all rights reserved, used by permission with permission).

Fig. 9. Perspective of Industrial inheritance design-roof garden (Copyright ©2020 Zhixiang Zhang all rights reserved, used by permission with permission).

Figure 10. Perspective of Industrial inheritance design-open plaza (Copyright ©2020 Zhixiang Zhang all rights reserved, used by permission with permission).

J. Assessment Variables

In order to evaluate the different design options, with the help of literature review, 24 comparable variables are selected that fit the design goals and special types of industrial transformation from various related indexes. The variables are as follows: material-related: area calculation, material value, material recycling, material reuse, and material maintenance; sustainability-related: air quality, green space area, water resources area, carbon emissions, temperature, and storm water management; surrounding area related: resident feedback, job creation, safety, transportation, and income; and environmental design related: identity, Industrial element retention, landscape, tourism value, health, species diversity, wayfinding system design and lighting design. The description concerning how to measure and utilize the variables is a long and lengthy discourse (about 24 pages) and can be found in a document by Zhang [50].

The alternatives and variables are a evaluated following the Friedman Analysis of Variance by Ranks illustrated in (1) [51]. The equation approximates a Chi-square distribution. In the case of ties, the result is adjusted by dividing the result by a formula (2).

$$x_r^2 = \left(\frac{12}{bk(k+1)} \sum_{j=1}^{k} R_j^2\right) - 3b\,(k+1) \quad (1)$$

Where:
X is Chi-square
b is the number of blocks
k is the number of treatments
R is the sum for ranks of each treatment

$$1 - \sum_{i=1}^{b} T_i / bk\,(k^2 - 1) \quad (2)$$

Where:

$$T_i = \sum t_i^3 - \sum t_i$$

t_i : is the number of ranks tied by a specific rank in the block

If the results identify that at least one treatment is significantly different than another, a multiple comparison test can be applied to determine which treatments are significantly different (3).

$$\left| R_j - R_{j'} \right| \geq z\sqrt{\frac{bk(k+1)}{6}} \quad (3)$$

Where:

R_j and $R_{j'}$ are the sums of two different treatments

IV. Results

Table 1 presents the ranks of the variables from the three treatments investigated. Applying the equations to compute the calculated Chi-Square value, the calculation rendered the value of 9.51, and by looking for our k-1 degree of freedom through the table, we can find the degree of freedom as 2. With our error a being 0.05, we can find in the table that the value if X with 2 degrees of freedom is 5.991. As 5.991 is smaller than our data of 9.51, the hypothesis is accepted and the null hypothesis that there is not significant difference between the treatments is rejected. In other words at least one design is better than another ($p \leq 0.05$).

TABLE I. RANKS OF VARIABLE VALUES FOR TREATMENTS

Variable	Green environment design	Traditional renovation design	Industrial inheritance design
Industrial material area	3	1	2
Material Value	2	3	1
Material recycling	3	1	2
Material reuse	1.5	3	1.5
Material maintenance	2.5	1	2.5
Air quality	1	3	2
Green area,	1	3	2
Water resources area	1	3	2
Carbon emissions,	1	3	2
Temperature	1.5	3	1.5
Stormwater management	1.5	3	1.5
Resident feedback	3	1	2
Job creation	3	2	1
Safety	2.5	2.5	1
Transportatio n	3	1.5	1.5
Income	3	1.5	1.5
Identity	2	3	1
Industrial preservation	3	2	1
Landscape	1.5	3	1.5
Tourism value	2.5	2.5	1
Health	2.5	2.5	1
Species diversity	1	3	2
Wayfinding system design	3	2	1
Lighting design	3	2	1

TABLE II. TREATMENT DIFFERENCES

Design Scenarios Combinations	Difference
Green environment design & Traditional renovation design	3.5
Green environment design & Industrial inheritance design	15.5
Traditional renovation design & Industrial inheritance design	19

In a multiple comparison test, the computations revealed that the absolute value in differences between treatments must be greater than 16.7 (4). Table 2 presents the differences between the treatments. Only the traditional design is significantly different than the industrial inheritance design, all other comparisons are not significantly different ($p \leq 0.05$).

$$z\sqrt{\frac{bk(k+1)}{6}} = 2.41\sqrt{\frac{24\times 3(4+1)}{6}} = 16.7 \quad (4)$$

V. DISCUSSION

A. *Interpretation of the Results*

The results of Friedman's test support that the design of one site has at least a statistically significant advantage over another site. Through the final analysis of the overall ranking results, the final design focusing on industrial heritage protection has overall advantages over traditional designs, which basically meets program goals and expectations. In this study, a total of three design schemes were constructed, including 24 variables, and a Friedman statistical test was performed, resulting on some observations.

The first observation is about the results concerns materials. Green environmental design can be said to contain many plants. The main advantage in terms of materials is that it has a high possibility of reuse, as plants can be easily reused by removal. Compared with the direct destruction of certain materials, it is more environmentally-friendly and sustainable, but the daily maintenance costs of those plants are much higher than traditional renovation design. Secondly, the materials “left-over” from the industry can be reused to save costs and increase the value of the site, which makes the value of industrial heritage design the highest. The traditional design has obvious advantages in terms of materials, mainly from an economic aspect It is convenient to recycle and thus can reduce expenditure, and it requires less maintenance. However, the traditional design does not provide much support for the environment and sustainability.

Therefore, it is somewhat obvious that in terms of environmental protection and sustainable development, traditional renovation design is at a disadvantage in all aspects, while industrial heritage design and green design have played a significant role in improving the surrounding environment. Through a series of comparisons in air and rainwater management, one can find that plants have a huge improvement effect on the site. The traditional renovation project that maintains the original style of the site and has the largest usable space may have some popularity among local residents. The reason is that the design not only preserves many original features, but also provides the local residents with improvements to their lifestyle.

In the research study, it was thought that the protection of industrial heritage may be much better than the other two designs, in fact, after applying the statistical test, the design of industrial heritage cannot be statistically separated from the green design. The heritage design ranks higher in the overall ranking, but it has not reached the value that can be judged to be better than the green design. The traditional design has been demonstrated to have few advantages over the industrial heritage design. Based on these two points, compared with the green design and industrial heritage design, the biggest difference in the traditional design apparently lies in the degree of greening. Traditional design is mainly designed to renovate the land for beautification and other objectives, because the site is well preserved, particularly, the programmatic item of preserving the original building as much as possible; while the greening and other ecological improvement measures are only kept at the minimum standard. Although traditional design may have the most practical space for activities compared with green environment design and industrial heritage design, it generates problems, such as water resources management. The greening can enrich the environment and provide a stronger function of stormwater management. Because of its inabilities, the traditional design does not take into account new concepts such as sustainable development and rainwater management, which leads to a large difference with the industrial heritage design.

The industrial heritage design generated the highest score in the overall ranking, which can be inspirational to designers intent upon a cultural link with industrial land transformation design. The land contained a very typical old factory with plans for renovation, and it does not have the universality of the other famous large-scale transformation projects that are now popular in Shanghai. Although it is just a very ordinary old food factory, its location is relatively closer to the urban area compared to other large-scale projects. Some elements of the original design, especially the building structures, can be preserved for renovation to avoid the loss caused by renovation and reconstruction. Scattered materials and tools can be retained as landscapes in the site to increase the overall industrial elements. In addition, because of the location of the city, the site must serve the surrounding residents, so the reserved site must have a certain degree of functionality, such as having a sports space or an activity area. Although the green environment design has an advantage on maintaining a sustainable ecology as it is outstanding from the perspective of sustainable development, aesthetics, and the environment, the final value still has a narrow gap with the industrial heritage design, because it lacks a certain degree of functionality. For instance, the green space analyzed before is only used as an ecosystem or simply an aesthetic decoration, but it does not provide pedestrian and activity space, especially in densely populated cities. In addition, economic services should also be considered. The industrial heritage design is better at providing welfare and convenience for local residents while taking into account the ecological environment.

Through the discussion about the entire design, it is apparent that the industrial heritage design considers many factors. So no matter if one is looking at economical or aesthetic factors, it never ranks as the worst design compared with the other two designs. As a whole, it performs better at the overall design level, which is the reason why the industrial heritage design can obtain more advantages than the other two designs.

Although traditional renovation design and green environmental design are undoubtedly excellent in some aspects, they cannot take into account certain factors, and they do not highlight the special environment of industrial land. In comparison, industrial heritage design not only transforms those seemingly unfavorable factors into unique features, but also can contain more elements.

In addition, the merits of industrial heritage design can better inspire subsequent industrial heritage renovation design projects from the following perspectives. First, designers can consider establishing an ecological environment system, controlling the green space, and using rain gardens, green roofs, and indoor open planting methods to effectively utilize the space. Second, by taking into account the function of the venue, the designers can think about how to develop the venue to bring more convenience to residents' activities, such as converting the transformed space into skateboard parks, basketball courts, indoor spaces, and so on. Third, the designers should also consider preserving the memory of the site and extracting the original industrial elements of the site for analysis and transformation. For example, maybe the scattered steel frame structure can be turned into a landscape sculpture, and the original factory building can retain its iron doors and windows to display as a supermarket or restaurant with a unique style. From these perspectives, the development and design of the original industrial land will be more suitable for the future development of the city.

B. Limitations

This research has limitations in many aspects. The first is about the choice of sites. Because the site is an old food factory, lacks many common features that may be found on industrial sties. Because the food factory does not have toxic conditions on the site as other typical industrial land does, all designs here are based on the same assumption that no toxic elements remain on the site, which is a rare condition for many industrial lands. Secondly, it is quite close to the city center, but industrial lands in the city center are usually the first to be demolished, so more industrial lands are concentrated in the suburbs, which means that the supporting facilities are not as comprehensive as the sites in this study.

The second limitation is about the variable research. Although this article provides a total of 24 variables, there are more variables that are difficult to compare, such as noise isolation, taxation, etc., because of the difficulty in data collection and the scarcity of relevant studies. Additionally, the biggest limitation is that there is a certain degree of errors and subjectivity in many variables. Because many types of information do not have a clear method for quantitative comparison, the pros and cons of comparisons can only be judged through measures such as estimating. Some variables that could be evaluated through questionnaires, but in this investigation are assessed with subjectivity. In addition the values of experts and the public are often different, resulting in the interpretation of built form often diverging from public norms [28,

Finally, all design changes will affect the final results of the test, which means that if one change any part of the design, the results may be different. The most critical part of the Friedman test is the number of variables and design options, so the ranking changes caused by some numerical arrangements or one of the design changes will greatly affect the final research results.

VI. Conclusion

In recent years, the transformation of urban industrial land has become a typical problem in the process of urban development. After a certain amount of large-scale and well-known industrial land has been transformed, ordinary traditional factories and industrial land with influence only in the local area catch the designer's attention. Many lands have been rudely demolished, rebuilt and turned into new landscapes. In a sense, these original special architectural and industrial elements are also a type of usable value. These special values are studied and discussed in this article, with a contemplation on how to give them new vitality and how to better protect them.

After comparing three typical representative designs with 24 variables, the final conclusion is that the design that focuses on the transformation of industrial heritage projects not only has a small gap with the traditional designs in the aspects where traditional designs usually have obvious advantages, but also has great contributions to sustainability and the surrounding environment. The design has injected new vitality into the entire site and created unique values, giving troublesome abandoned industrial element a better solution. The design plan comprehensively provides the community with more gathering spaces and community gardens, which brings many visible short-term benefits and long-term environmental improvement to surrounding residents, and also provides residents with more opportunities to interact with community members. In the end, the conclusions reached prove that these industrial elements not only cause no pollution and additional costs, but also can be integrated into the design to create a better industrial transformation design. Although there are many limitations and subjectivity in the article, the variable design and design ideas of this research can also provide inspirations for future industrial transformation.

In general, the design guidelines of this study will enable industrial elements to find their place in industrial transformation land and obtain safe and beautiful benefits in the future. In addition, future studies may consider more variable comparisons and the value brought by industrial elements in the design. These studies will contribute to the future development and progress of cities.

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