



ENCOREstate

ENabling Circular CONstruction to public space REgeneration
in Shanghai new workers' estates

COURSE
AR3U100 | Graduation Lab: Urban Transformation and Sustainability

MENTORS
Alexander Wandl
Rients Dijkstra

STUDENT
Yiran Li | 4821092

DATE
22-6-2020



All images, graphics, diagrams are by the Authors unless otherwise mentioned.
Source for all maps: Map data copyrighted OpenStreetMap contributors and available from <https://www.openstreetmap.org>
Sources for additional data in the maps are mentioned in the caption of the maps.

CONTENT

CHAPTER 1 PROBLEMATIC ANALYSIS	6
1.1 MOTIVATION	9
1.2 HISTORICAL REDEVELOPMENT MODE	10
1.3 CONSTRUCTION & DEMOLITION & DECORATION WASTE (CDDW)	17
1.4 CDDW UNDER THE HISTORICAL DEVELOPMENT MODE	18
1.5 THE HARM OF CDDW	20
1.6 ENVIRONMENTAL EFFECT OF NEW MATERIAL PRODUCTION	22
1.7 CDDW TREATMENT IN SHANGHAI	23
1.8 NEW WORKERS’ ESTATE (OLD PUBLIC HOUSE)	24
1.9 CURRENT PROBLEMS OF NEW WORKERS’ ESTATES	28
1.10 REGENERATION OF NEW WORKERS’ ESTATES	31
1.11 OPPORTUNITIES	33
1.12 OTHER CHALLENGES	34
1.13 PROBLEM STATEMENT	35
CHAPTER 2 METHODOLOGY	36
2.1 RESEARCH QUESTION	38
2.2 RESEARCH AIMS	39
2.3 CONCEPTUAL FRAMEWORK	40
2.4 PROPOSED RESEARCH APPROACH	45
2.5 CONCLUSION	49
CHAPTER 3 THEORETICAL UNDERPINNING	50

CHAPTER 4 REPRESENTATION ANALYSIS	60
4.1 DISTRIBUTION AND STATUS OF NEW WORKERS’ ESTATES	62
4.2 THREE TYPES OF NEW WORKERS’ ESTATES	71
4.3 SAMPLE 1- MAINTAIN : CAOYANG ESATATE	72
4.4 SAMPLE 2- REFURBISHMENT : NANLING ESATATE	76
4.5 SAMPLE 3- DEMOLITION : PENGPU ESTATE	79
4.6 CONCLUSION	81
CHAPTER 5 PROCESS REGENERATION AND EVALUATION	82
5.1 CURRENT REGENERATION MODE	84
5.2 REGENERATION MODE: MAINTAIN&REFURBISHMENT&DEMOLITION	88
5.3 EVALUATION OF REGENERATION	90
5.4 PUBLIC SPACE PROBLEMS	92
5.5 CONCLUSION	96
CHAPTER 6 CIRCULAR REGENERATION	98
6.1 BUILDING MATERIALS	100
6.2 CIRCULAR USE OF BUILDIDNG MATERIALS	105
6.3 CIRCULAR MATERIAL & PUBLIC SPACE	110
6.4 MATERIAL CONSUMPTION OF PUBLIC SPACE	111
6.5 CIRCULAR MATERIAL FLOW	118
6.6 CONCLUSION	121
CHAPTER 7 VISION&PRINCIPLE&STRATEGIES	122
7.1 VISION	124
7.2 PRINCIPLE	125
7.3 STRATEGY	126
7.4 TOOLBOX OF MODULES	130

CHAPTER 8 PUBLIC SPACE DESIGN	136
8.1 SITE ANALYSIS	138
8.2 GENERAL REGENERATION	140
8.3 SEMI-PRIVATE SPACE	148
8.4 PUBLIC SPACE	156
8.5 SEMI-PUBLIC SPACE	163
8.6 EVALUATION	170
8.7 CONCLUSION	171
CHAPTER 9 CIRCULAR CONSTRUCTION NETWORK	172
9.1 INTRODUCTION	
9.2 URBAN MINING- SUPPLY AND DEMAND	
9.3 CURRENT MATERIAL FLOW	
9.4 CIRCULAR MATERIAL FLOW	
9.5 SUPPLY AND DEMAND MATCH	
9.6 COLLABORATIVE NETWORK	
9.7 ROADMAP	
9.8 CONCLUSION: CIRCULAR CONSTRUCTION NETWORK	
CHAPTER 10 CONCLUSION	192
CHAPTER 11 REFLECTION	202
CHAPTER 12 REFERENCE	210

1

PROBLEMATIC ANALYSIS

Problem Field
Problem Statement

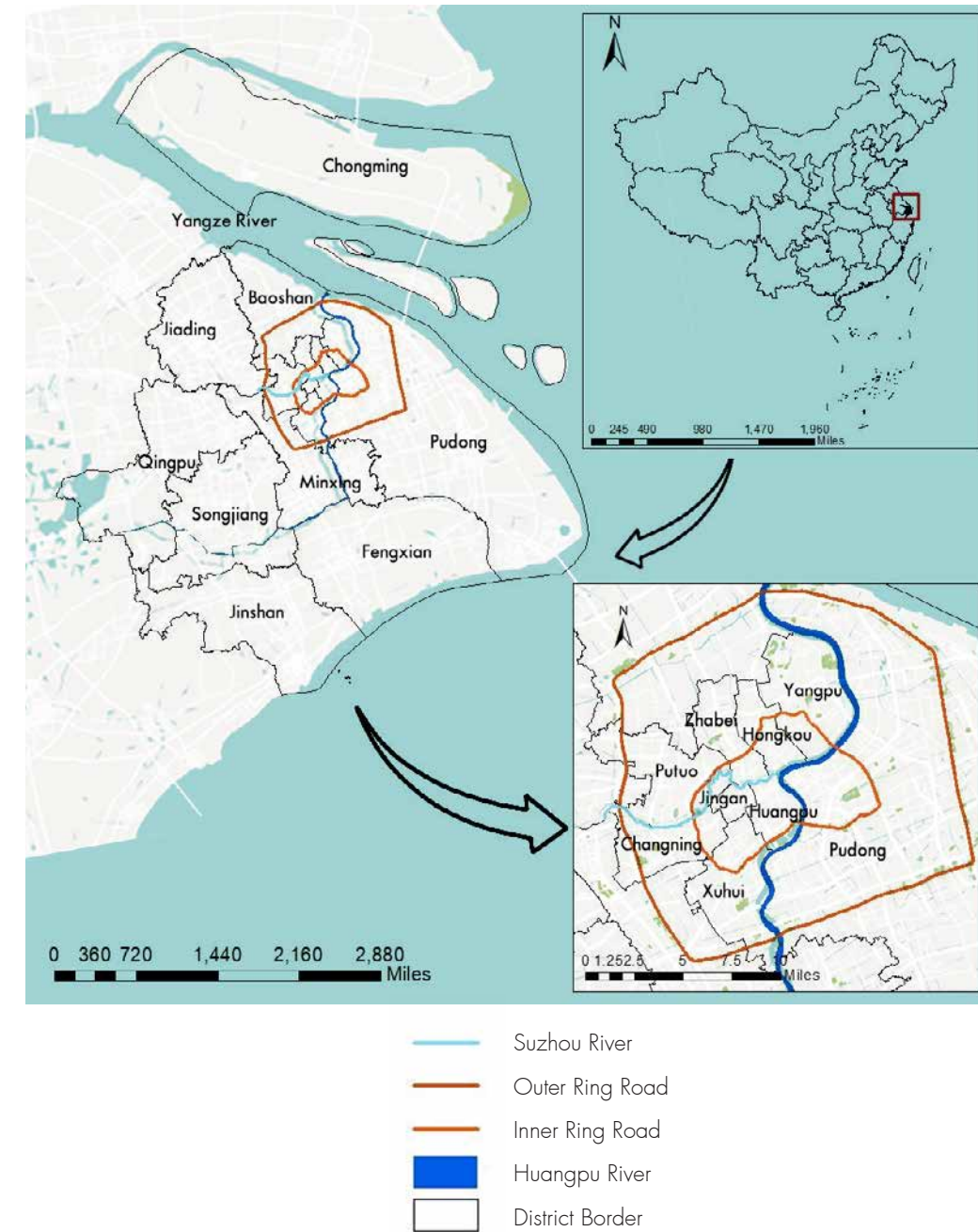


Fig. 1.1 | Map of Shanghai

Sources: Study on the evolution of urban residential space structure in Shanghai, Yang Junli, 2018
<https://snazzymaps.com/style/74/becomeadinosaur>



Fig. 1.2 | Photos of Shanghai

Sources:
<https://bezoekchina.nl/steden/shanghai/>
http://sym3381.lofter.com/post/2b95ad_725921e
https://news.online.sh.cn/news/gb/content/2018-12/03/content_9131257.htm

1.1 MOTIVATION

In the past decades of years, the urban development mode in China is demolishing the old flat residential buildings or the several-story buildings and regenerate into more dense urban areas.

Except for low-rise shanty houses and Lilong, the longest development history of residential estate form is the new workers' estate, which was built in the early days of the PRC. As time goes on, the existing situation of these estates gradually shows a lot of problems. Compared with cases from more developed areas, if we do not change the urban development mode timely, the future situation will be even worse.

The motivation of the project starts with the physical and social decay issues of the new workers' estates. The existing urban regeneration of low buildings has already generated a large amount of construction, demolition, and decoration waste. If we do not change the method of urban redevelopment to recycle these wastes, the transformation of new workers' estate will generate more waste and extract more resources from nature. As the Chinese cities building more and more high-rise areas as a solution to redevelop the urban area, the problem in the future will become more severe. Therefore, this project is, as a reminder, to find a new mode of redevelopment, facing the issues of the new workers' estates and the challenges of multi-story urban areas, trying to regenerate them sustainably and flexibly.

1.2 HISTORICAL REDEVELOPMENT MODE

1.2.1 Shanty Towns to New Workers' Estate

Before the founding of the PRC, there were a large number of shanty towns outside the concession (city center), where low-income people (mainly workers) lived here. In the early days of Shanghai's liberation, the government first increased infrastructure for shanty towns in Hudong, Zhabei, Nanshi, and other areas with limited funds, which improved the living environment in these areas. During this period, the reconstruction of the old houses was renewed by the government and various enterprises in response to the urgent need for improvement in housing conditions. The redeveloped houses are new workers' estates with complete facilities. Therefore, the area between today's inner ring road and middle ring road, combined with the layout of the industrial zone, has developed a large number of new workers' estates.

From the 1960s to the 1980s, the Shanghai Municipal Government aimed to improve the urban appearance of the city. During this period, the construction of residential buildings in the central urban area was mainly based on the expansion of existing new estates. The renewal of old houses in this period is mainly in two forms. One is to add floors to original houses and apartments with better foundations and structures so that the houses change from the original one or two stories to three or four stories in a short period of time. A large number of dwellings were rapidly added. Secondly, large and medium-sized shanty towns and deteriorated simple houses were demolished and rebuilt. Generally, the entire block was transformed, and the supporting facilities of municipal utilities and public services were improved. The construction has created good living conditions. (Liu Chenyang, 2019)

Fig. 1.3 and 1.4 shown, is the comparison of the locations of large workers' estates and shanty towns built in the early years of the PRC. We can find that most of the new workers' estates are located in the original shantytowns. Fig. 1.5 and 1.6 show the change in living space and the improvement of living quality.

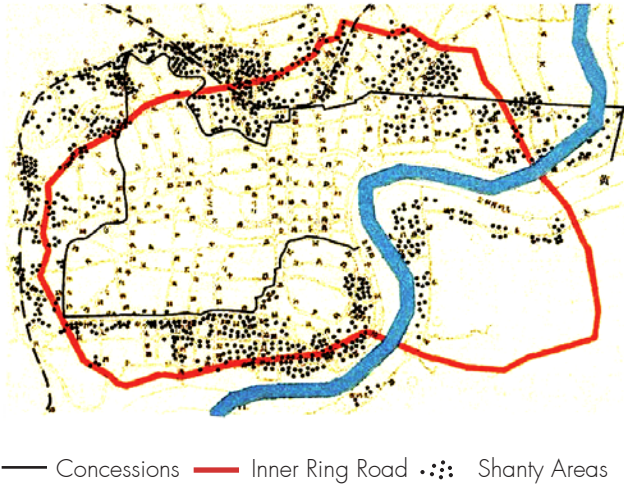


Fig. 1.3 | The location of shanty towns before before 1949

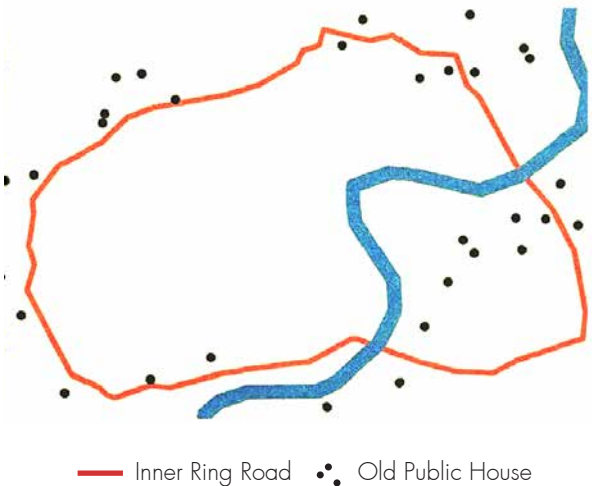


Fig. 1.4 | The location of large workers' estates in the early years of People's Republic of China (Xu Xiaofeng, 2019)



Fig. 1.5 | The old shanty towns in Shanghai



Fig. 1.6 | The new workers' esataes in Shanghai

Sources:
<https://xuyong.mala.cn/thread-12383236-1-1.html>
https://www.997788.com/pr/detail_339_4075052.html

1.2.2 Example: Fangua Alley

Fangua Alley is an essential example of this regeneration process. It is located south of the Shanghai-Nanjing Railway and west of Gonghexin Road. Before the liberation, it was called 'rolling ground dragon.' Formerly known as 'kiln shed,' it belongs to the worst kind of grass-root shed. It had no distinction between roof and wall and used a bamboo sheet as a skeleton to form a semi-circular shape. It was covered with broken reed mats and sacks. It was a place that is too small to turn around, and often had to be crowded with five or six people. Before liberation, the area was about 100 acres ('rolling ground dragon' accounted for 63%), and more than 16,000 people lived there, which is the shantytown with the highest population density in Shanghai, as shown in Fig.1.7.

In 1950, the Shanghai Municipal Government decided to begin the regeneration of shantytowns. In June 1963, the demolition and reconstruction of Fangua Alley began. In July 1964, the first phase of the new workers' estate was completed, and some residents moved into the new house. As of December 1965, the second phase of the new workers' estate was completed. Fangua Alley completed a total of 31 five-story buildings with reinforced concrete structures and held 8,781 people in 1964 households. It was one of the first new workers' estates in this city with five-story buildings. In the regeneration of Fangua Alley, a total of 26,900 square meters of simple shanty houses were demolished, turning an ordinary dwelling house with dense dwellings and poor public environment into a neat, beautiful, and convenient new workers' residential area, as shown in Fig.1.8. (CGEMA, 2017)

Fig.1.9 shows the comparison of Fangua Valley before and after the regeneration on height, building quality, and building scale.



Fig. 1.8 | The new workers' esataes in Shanghai

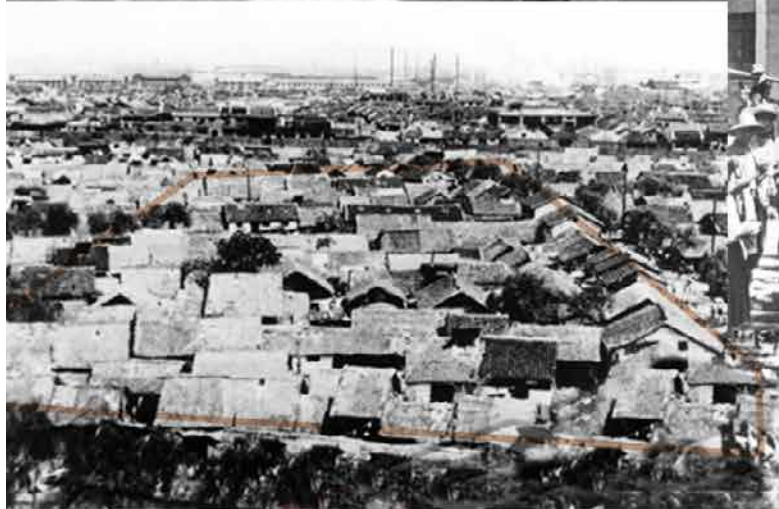
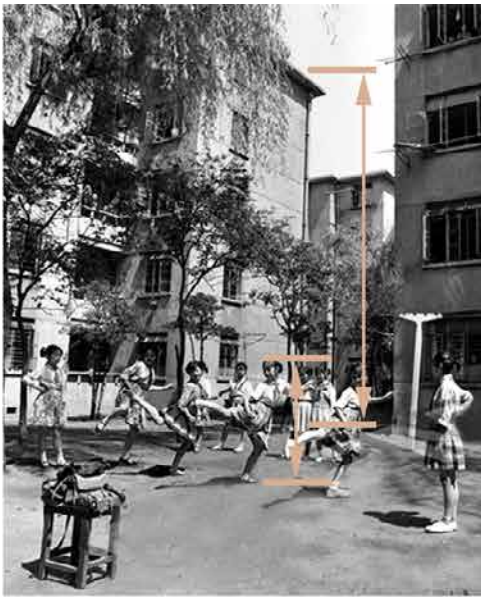


Fig. 1.9 | The comparison of Fangua Valley before and after the regeneration
Sources:
http://www.sohu.com/a/192195896_809597



Fig. 1.10 | Urban area of Shanghai in 1980s



Fig. 1.12 | Shanghai Lilong style building



Fig. 1.13 | Shanghai high-rise center

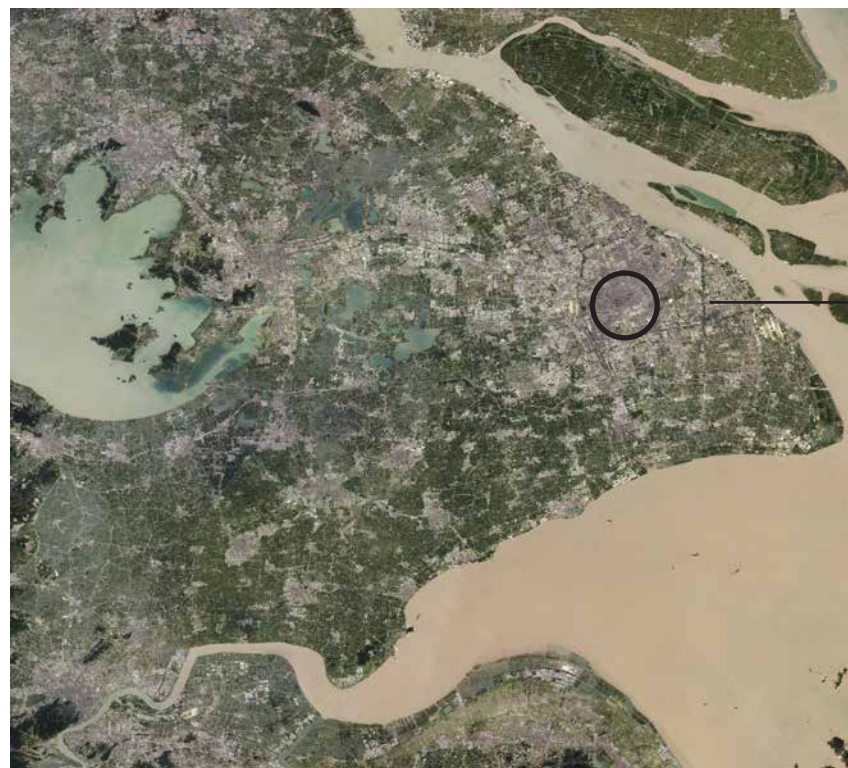


Fig. 1.11 | Urban area of Shanghai in 2010s



Fig. 1.14 | Shanghai suburban villages



Fig. 1.15 | Shanghai suburban estates

Sources:
<https://earthobservatory.nasa.gov/images/89853/sprawling-shanghai>
https://www.997788.com/pr/detail_339_4075052.html
<http://5b0988e595225.cdn.sohucs.com/images/20181128/e6d52a8c42fa4f7db7d4f2849d37932c.jpeg>
<http://www.novel520.net/image/3162813805/>

1.2.3 Flat Houses to Residential Estates

After 1978, the reform and opening up, Shanghai faced severe housing shortage and determined the development strategy of combining the construction of new areas with the reconstruction of the old regions. In reconstruction regeneration, the intensity of land development in the residential area was consciously increased. The economic, social, and environmental benefits were achieved.

In the early 1990s, the reform of the land-use system provided an active and stable source of funds for the regeneration of the old urban area, and the redevelopment of old residential districts in Shanghai started a rapid development. In 1992, the Shanghai Municipal Government established one of the key projects for the reconstruction of the 3.65 million square meters of deteriorated houses at the time. In the early stage of the implementation of the “365 Deteriorated Shed”, the Shanghai Municipal Government hoped that by attracting real estate developers to participate in the reconstruction of the old districts, the existing “deteriorated shed” will be demolished, and new housing will be built. The sales income will subsidize the cost of demolition and relocation, and some residents will move back to buy new house to realize the regeneration of the area. The “365 Deteriorated Shed” was very useful at the time. (Liu Chenyang, 2019)

Due to the continuous rise in land prices, the cost of redevelopment in the central area of the city has risen. The form of regeneration is mainly demolishing low-rise alleys, rebuilding high-rise buildings, and realizing urban renewal by improving the quality and density of living, as shown in Fig. 1.12 and 1.13. is the contrast before and after urban regeneration at the same site in the center of the city.

Due to urban spacial limitations, urban development has gradually expanded to surrounding suburbs. This development mode dismantles suburban villages, occupies the original arable land and natural environment, and develops large-scale residential estates. Fig. 1.14 and 1.15 show the comparison of the urban suburbs before and after urban development.

1.3 CONSTRUCTION & DEMOLITION & DECORATION WASTE (CDDW)

The process of city development and regeneration involves a large amount of material flow and generates material waste. This paragraph shows what is the definition of waste material relates to the building industry.

Because building waste has a wide range of sources and complex components, and it is often mixed with urban domestic waste, the definition of it is not clear (Haile, 2017). Many experts and scholars also have different views (Coronado, 2011). Building waste refers to waste materials that are unnecessary for the building itself during the construction, maintenance, demolition, and decoration of buildings and structures.

In this research, the building waste is divided into three categories according to the source. The waste related to the building industry includes waste from the construction of new buildings, waste from the demolition of old buildings, and waste from the decoration of buildings, as shown in Fig. 1.16.

- Construction waste:** It is waste generated during the construction process, including construction mud, packaging materials of construction materials, and construction materials that are not entirely used during construction.
- Demolition waste:** It is the waste generated during the demolition of old buildings. The composition of demolition garbage generated by different building structures is different, mainly including brick, concrete, steel, and other materials.
- Decoration waste:** Its composition is more complex, including materials that were not fully used in the decoration process, packaging materials, and waste building components and furniture.



Fig. 1.16 | Photos of CDDW

The waste of demolition of buildings accounts for 58% of total building waste, the construction waste accounts for 36%, and decoration accounted for the smallest proportion, 6% (Zhu Dongfeng, 2010), as shown in Fig. 1.17.

Therefore, the waste materials relate to building process in this research are called construction, demolition, and decoration waste, in short, is CDDW.

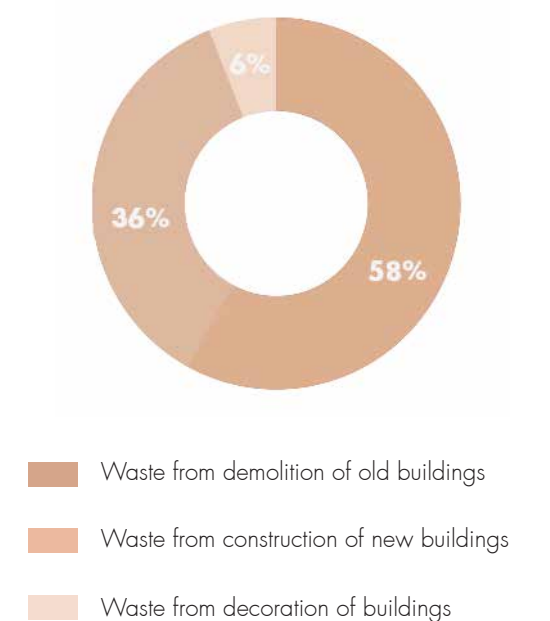


Fig. 1.17 | Composition of CDDW in China

Sources:
<http://zohi.tv/p/56025.html>
<https://www.schouten.ca/>

1.4 CDDW UNDER THE HISTORICAL DEVELOPMENT MODE

1.4.1 Amount of Development

Since 1992, the Shanghai government has intensified the regeneration of the old city and has old city reconstruction plans for three times. In 1992, the problem of the housing shortage in Shanghai was prominent. Shanghai implemented the “365” dangerous shack renovation plan, which was completed by the end of the 20th century. In the second round of the old housing regeneration in 2000, the plan of “demolition, modification, and retention” was adopted. In 2001, the second round of aged reforms was implemented. The planned old regeneration area was 7 million m², and 280,000 households benefited. In 2005, the Shanghai government proposed that Shanghai plans to complete the remaining old city renovations within ten years. (Yang Junli, 2018)

The inner-city land area of Shanghai expropriation (demolition) from 1995 to 2015 is shown in Figure 1.18, and the new housing development is shown in Figure 1.19.

By comparing Fig. 1.18 and Fig. 1.19, it concludes that both the old low-rise houses demolition speed and new housing development speed in the inner city have been slowed down in recent years. More dense estates like the new workers’ estates have replaced some low-rise shanty houses. These low-rise houses are mostly with development potential, low difficulty in demolition, and no significant preservation value. However, when it comes to the higher and larger estates, the demolition difficulty is great, while the profit is low. Therefore, the inner-city regeneration speed is slowing down.

1.4.2 CDDW Under Existing Development

Under the existing development and redevelopment mode, there is a large amount of CDDW generated, as shown in Fig. 1.20. In recent years the amount of waste grows with the years. The amount of CDDW per year has already reached 180 million tons. That means, at its peak, the CDDW generated in Shanghai in 4 days is equivalent to a Jinmao Building (Fig.1.21)

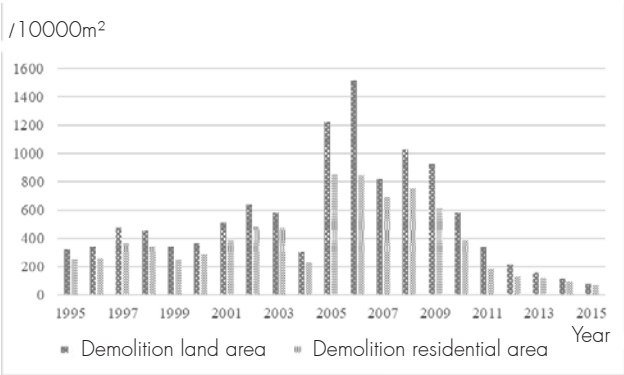


Fig. 1.18 | 1995-2015 Shanghai Demolition Land Area

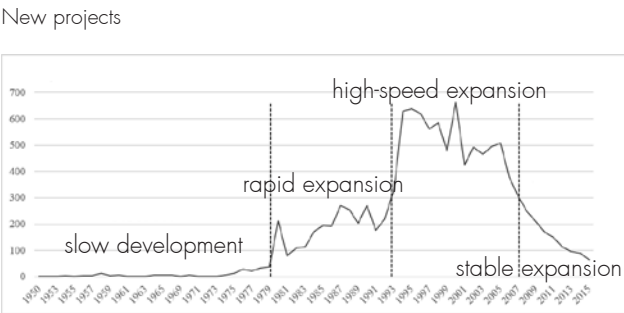


Fig. 1.19 | New Housing Development in Shanghai (data from 2016 Shanghai Statistical Yearbook)

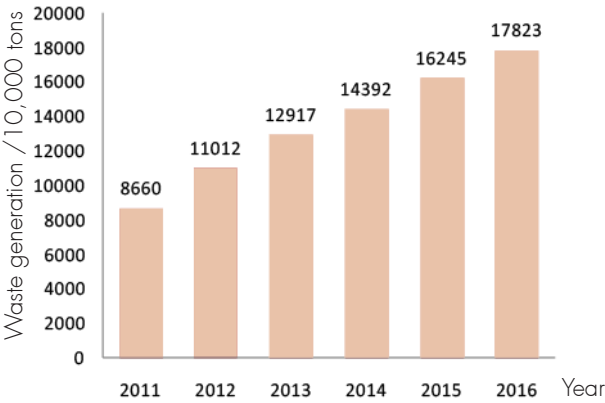


Fig. 1.20 | CDDW in Shanghai (data from Qian Yaoli, 2019)



x 4 days



Fig. 1.21 | Composition of CDDW in China (data from Zhengzhou Dingsheng Company)

Sources:
http://m.sohu.com/a/159487796_689064
Exploration and practice of standardization of comprehensive utilization of construction waste in Shanghai, Qian Yaoli,

Sources:
<https://www.khl.com/construction-europe/demolition-when-you-break-it-all-down/140781.article>
http://blog.sina.com.cn/s/blog_92632f3e0102w20j.html

1.5 THE HARM OF CDDW

1.5.1 Environmental Harm of CDDW

1. The destruction of soil by stacking construction waste is severe. The CDDW piled in the open-air enter the nearby soil, will pollute the soil, and reduce the productivity of it. Chemical reactions will occur under the influence of various factors, which will increase the content of heavy metals in the soil and increase heavy metals in nearby crops.
2. During the storage and landfill process of CDDW, sewage is leached out due to fermentation and leaching of rainwater, and soaking of surface water and ground-water, which will cause severe damage to the surrounding surface water and ground-water. There are large amounts of hydrated calcium silicate and calcium hydroxide contained in waste mortar and concrete. There are large amounts of sulfate ions contained in waste gypsum. At the same time, waste cardboard and waste wood decompose to produce organic acid. The leachate water from CDDW at the storage site is generally strongly alkaline. It has a large number of heavy metal ions, hydrogen sulfide, and a certain amount of organic matter. If it is not managed and flows into rivers, lakes, or penetrate the ground, it will cause surface water and ground-water pollution. After the water is polluted, it will directly affect the survival of aquatic organisms and the quality of water resources. Once people drink contaminated water, it will cause great harm to human health.
3. In the process of stacking CDDW, under the action of temperature and moisture, some organic substances will decompose and generate harmful gases. For example, waste gypsum contains a large number of sulfate ions. Bacteria and dust in the garbage are scattered with the wind, causing pollution to the air. A small amount of flammable CDDW will generate toxic carcinogens during the incineration process, causing secondary pollution to the air.
4. The temporary storage areas affect city appearance. It is inevitable to cause problems such as waste scattering, dust, and ash in the air during transportation, which seriously affects the appearance and landscape of the city. It can be said that the CDDW has become an essential factor that damages the city's green space and is a destroyer of the city's appearance. (Meng Xiaoyue, 2012)

1.5.2 Spatial Limitation of Landfill Treatment

At present, the main treatment method of CDDW in China is to bury it underground. It occupies a lot of land. With the increase in the amount of CDDW, the number of garbage infill sites is also increasing, and the area of waste dumps is gradually expanding. The phenomenon of garbage competing with people for land has been very serious.

China's biggest dump is already full, 25 years earlier than planned, as shown in Fig. 1.23. People forced the garbage infill to accept four times as much trash per day as it was designed for. The landfill has reached the maximum carrying capacity in space and volume.

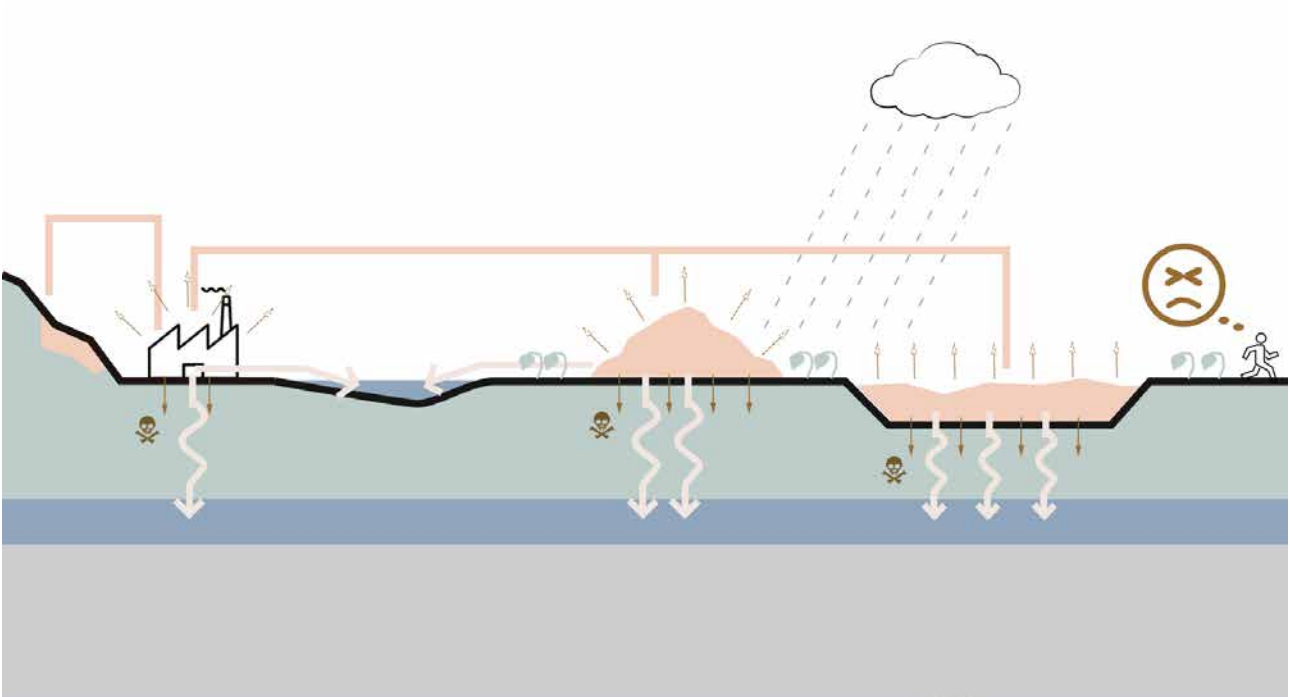


Fig. 1.22| Harms of CDDW



Fig. 1.23| Largest landfill at capacity

1.6 ENVIRONMENTAL EFFECT OF NEW BUILDING MATERIAL PRODUCTION

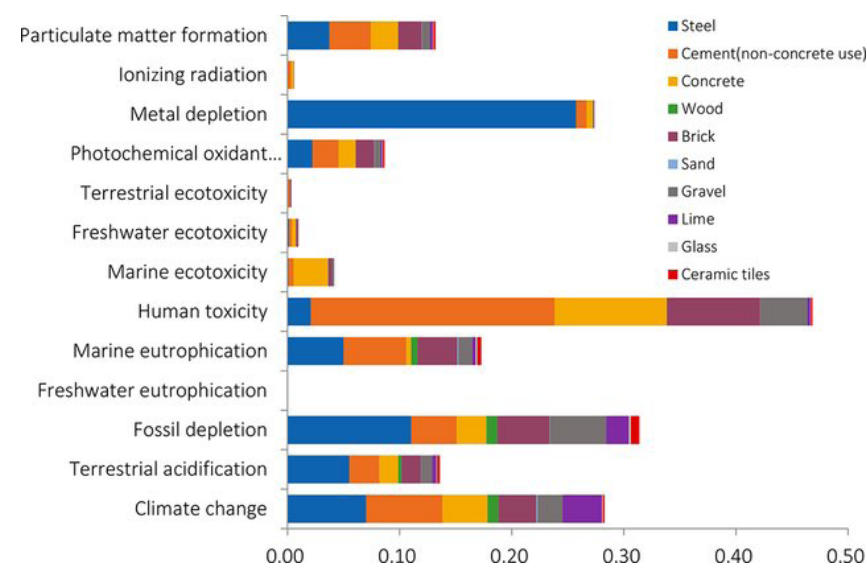


Fig. 1.24| Environmental impact of building materials (Huang Beijia, Zhao Feng, 2018).

In addition to the negative impacts of discarded building materials on the environment, the production of new building materials required to meet a large number of constructions will also have an impact on the environment (Hossain, 2018), as shown in Fig.1.24.

Take the cement industry as an example. Cement plants are a significant source of sulfur dioxide(SO2), nitrogen oxide (NOx) and carbon monoxide (CO), which can cause or contribute to a variety of health problems and adverse environmental impacts, such as ground-level ozone, acid rain, global warming, water quality deterioration, and visual impairment (The Economic Times, 2019). There are also heavy metals trapped in the dust that falls to the ground with rainwater, further polluting soil and water sources.

A ton of cement yields at least half a ton of CO2, according to the European Cement Association, which is more than the average car would produce on a drive from New York to Miami (The Economic Times, 2019). According to data from China Cement, at least 3 tons of materials (including various raw materials and fuels) are consumed for each ton of cement production, including 1.3 tons of limestone (main raw materials), 200 kg of coal, 80 kWh of electricity, and 0.8 tons of

carbon dioxide and a large number of harmful gases and particles such as sulfur dioxide and dust (China Cement).

Besides, for every 100 million bricks produced, 1.3m x 104 m² of land will be used, which seriously damages China's arable land resources. Iron production requires mining and destruction of natural landscapes. Each ton of steel produced consumes 1.66 tons of standard coal and 48.6m³ of water. Sand and gravel, which account for 70% to 80% of concrete material composition, need to extract the mountains and river beds. This can easily lead to water loss, soil erosion, and river diversions. (Qin Huahu, 2011)

From the above data, we understand that the number of raw materials and other materials to be used in the production of building materials is large. People need to extract a large number of resources from nature and cause damage to the ecological environment. At the same time, in the production process, energy and materials are consumed, and high carbon emissions and pollution are generated, which has a negative impact on the natural environment.

1.7 CDDW TREATMENT IN SHANGHAI

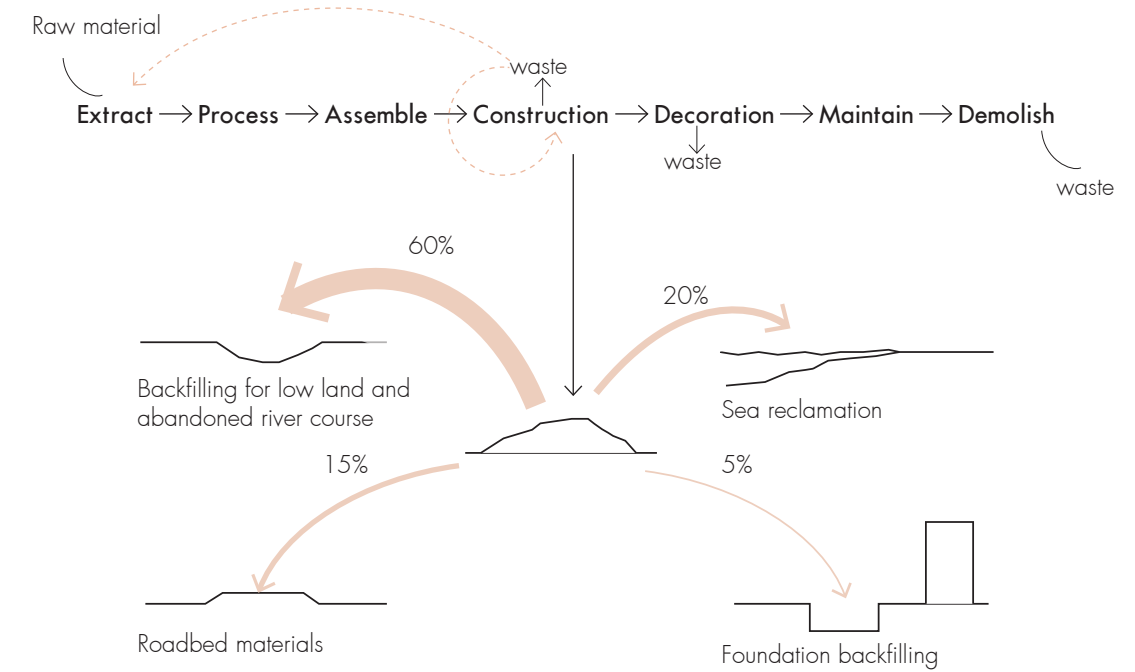


Fig. 1.25| Construction waste treatment in Shanghai

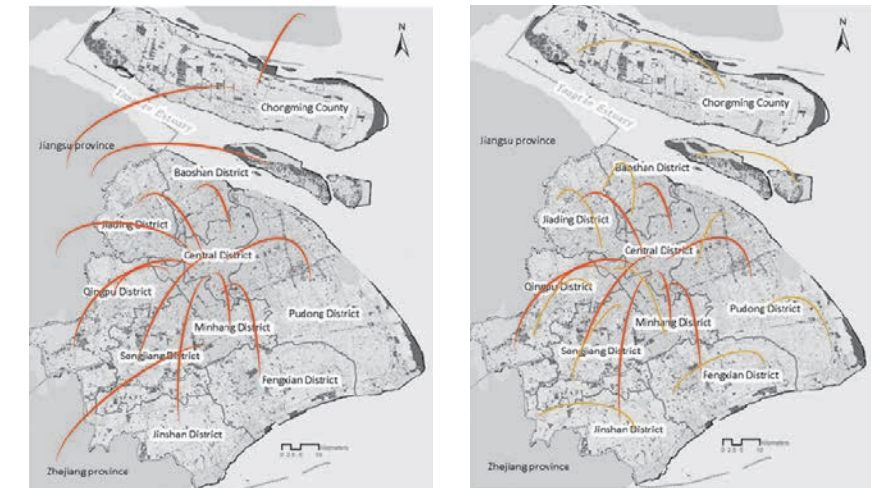


Fig. 1.26| Construction waste flow in Shanghai before and after 2016

Shanghai's current treatment of CDDW is focused on construction mud. According to the information from Shanghai Landscaping & City Appearance Administrative Bureau, there are mainly the following types of construction mud circular treatment in Shanghai: First, backfilling for low land and abandoned river course, which accounts for about 60%; second, sea reclamation, which accounts for about 20%; third, the production of recycled aggregate as roadbed materials is about 15%; Fourth, foundation backfilling, which accounts for about 5% (CHYXX, 2018).

From 2009 to 2010, Shanghai implemented a "consistency-consumption" construction mud program. It refers to the correspondence between the central city and the suburbs. A target-clearance point is set up in the suburbs to absorb the debris from the city center. Since July 2016, Shanghai has implemented the construction of "overall (network) consumption in the city center and self-consumption in the suburbs" of construction waste and prohibits the transportation of waste to other cities. In Fig.1.26, it shows the construction mud flow before (left) and after (right) 2016.

However, most of these circular materials are downcycled reused, and there are still many CDDWs that have not been used as resources. Shanghai still has great potential to improve the utilization of CDDW resources.

1.8 NEW WORKERS' ESTATE (OLD PUBLIC HOUSE)

Since the reform and opening up, China has gradually carried out a series of political and economic reforms and entered a period of transition. In the process of transformation, along with the process of globalization, great changes have taken place in the residential spacial structure of Shanghai. Land market reform and residential commercialization reform have the greatest impact on residential spatial structure, and Shanghai's real estate market has gradually developed (Wand Dan, 2010).

In the 1950s~1990s, as a representative residential form after the founding of the PRC, New Workers' Estates met the housing requirements of millions of "worker class." They once occupied the most important position in Shanghai's urban area.

It was named new workers' estate at that time, and people sometimes call them old public house now. The construction of the new estate for workers in China coincides with the period of recovery and development after China's liberation. Its significance is not limited to the improvement of living quality. At that time, it represented the superiority of the socialist state system. At the same time, it is an accurate and realistic reflection of the improving life of the Chinese people. (Ding Guijie, 2007) After undergoing the regeneration of shantytowns and low-rise alleys, New Workers' Estate is the longest existing residential community in Shanghai. It has the most enormous potential and demand for further regeneration.

In the early days of liberation, 60% of China's industrial workers were concentrated in Shanghai. However, the living conditions of industrial workers were deplorable. The government decided to improve the living quality of the working class. In 1951, the Shanghai Municipal Government established the "Shanghai Workers' Housing Construction Committee" to introduce the concept of "new workers' estate" from the Soviet Union to solve the housing shortage of three million industrial workers in Shanghai. (Li Fengqing, 2012) In April 1952, 20,000 workers' houses were built in the city.

From the beginning of the construction of the first new workers' estate (Cao Yang New Village) to 1978, the new workers' estate has been the main paradigm of Shanghai's housing construction, especially during the period from 1954 to 1958. Eleven new estates sites were developed, and 126 new estates were built, covering an area of about 13.08 million m², accounting for nearly two-thirds of the total new estates' construction between 1949 and 1978. However, with the reform and opening up in 1978, especially when the market economy was gradually established after 1990, the new workers' estate mode with distinctive characteristics of the past era is facing changes in the new social environment. In the 1990s, when state-owned enterprises were reformed, millions of workers in Shanghai were laid off. The tide of laid-offs stopped the new workers' estate development. (Yang Chen, 2019)

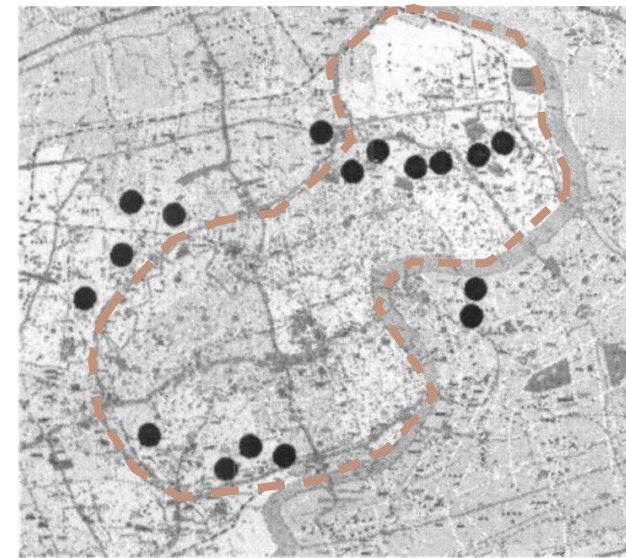


Fig. 1.27 | Location of new workers' estates built in 1950s

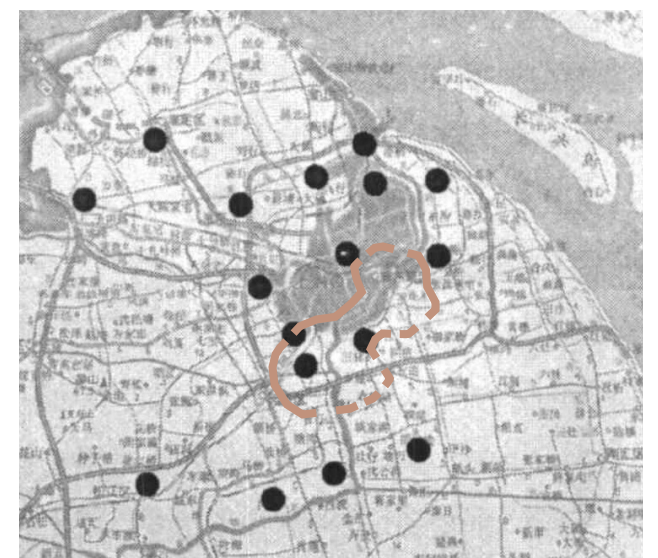


Fig. 1.28 | Location of new workers' estates built in 1960s



Fig. 1.29 | Different types of residential estates in Shanghai (data from ' Shanghai Residential 1949-1990)



Fig. 1.30 | Construction area of workers' estates in Shanghai (data from ' Shanghai Residential 1949-1990)



Fig. 1.31| Photos of New Workers' Estates

The distribution of new workers' estates is determined according to the urban development blueprint and the need in different periods of Shanghai's urban development. With the transformation of Shanghai from a consumer city to an industrial city, the overall urban development focused on the adjustment of the industrial structure and layout. In the early stage, the development of suburban industrial zones was the main focus, and in the later period, there was a plan to develop satellite cities. Most of these new residential estates are planned to be located at the edge of the urban area at that time, to make full use of the original public facilities in the urban area. The transportation of employees to and from work is convenient. Later the location of the new workers' estates is planned to be located in the suburban industrial areas and satellite cities. At the same time, the urban area, combined with shanty town regeneration, also makes appropriate use of some empty land for construction.

Workers from multiple plants share new workers' estate, and the public supporting facilities are uniformly managed by the government to form a complete service system. The principle of the layout of the new workers' estate is to arrange the location of the new residential estate following the industrial distribution location and the requirements of the workers' production and living nearby. They must be close to the industrial area and shorten the travel time of employees to and from work as much as possible. They should also keep a proper distance from industrial areas to prevent the invasion of harmful gases and noise in industrial production. Fig. 1.27 and 1.28 are summaries of the distribution of "new workers' estates" in Shanghai in the 1950s and 1960s.

From the construction of the first new workers' estate in the 1950s to the 1990s, the number of the new workers' estates accounted for an increasing proportion of the total housing in Shanghai, as shown in Figure 1.30. 1950-1960 was the period when the number of construction new workers' estates was the largest. After that, there was still a certain amount of new workers' estates' construction each year (Ding Guijie, 2007).

The space of the new estate replicates the buildings with a single style and arranges them orderly together to form a specific residential estate. The facade style is simple, monotonous, and lacks personality (Fig. 1.31). The design of internal living areas (such as public toilets and the kitchens) is also simple and crude.

1.9 CURRENT PROBLEMS OF NEW WORKERS' ESTATES

1.9.1 Physical Problem

- **The deteriorated exterior has a negative impact on urban environmental aesthetics, and the shabby interior leads to a low living quality.**
After decades of use, the building's facade, walls, and pavement were damaged, and the stairs, corridors, doors and windows, and the interior of the building were also ruined. When being built, the interior design was unreasonable, the rooms were too small, and the shared kitchen and bathroom caused inconvenience to life.
- **Facility damage**
Public infrastructure such as water, electricity, and heating facilities are aging. The building lighting, security monitoring, and elevator equipment are also facing physical decay. This decay will also cause a decrease in living quality.
- **Structural problems cause building safety hazards**
For some buildings that have been built for a long time and have poor structure quality, there may be structural dangers, as shown in Figure 1.32, which is an extreme situation and the building falls. For the old public houses, due to the low level of construction technology and the pursuit of construction speed, the service life of the building structure may be short.
- **Poor public space**
When the new workers' estate was built, the number of dwellings, not the quality, is pursued. Therefore, not enough attention is paid to the design of public space. In some new workers' estates, there is almost no open space, or the public space is dilapidated, or it cannot meet the needs of current public activities.
- **Weak ability to face disasters(earthquake, fire, hurricane)**
- **High energy consumption**

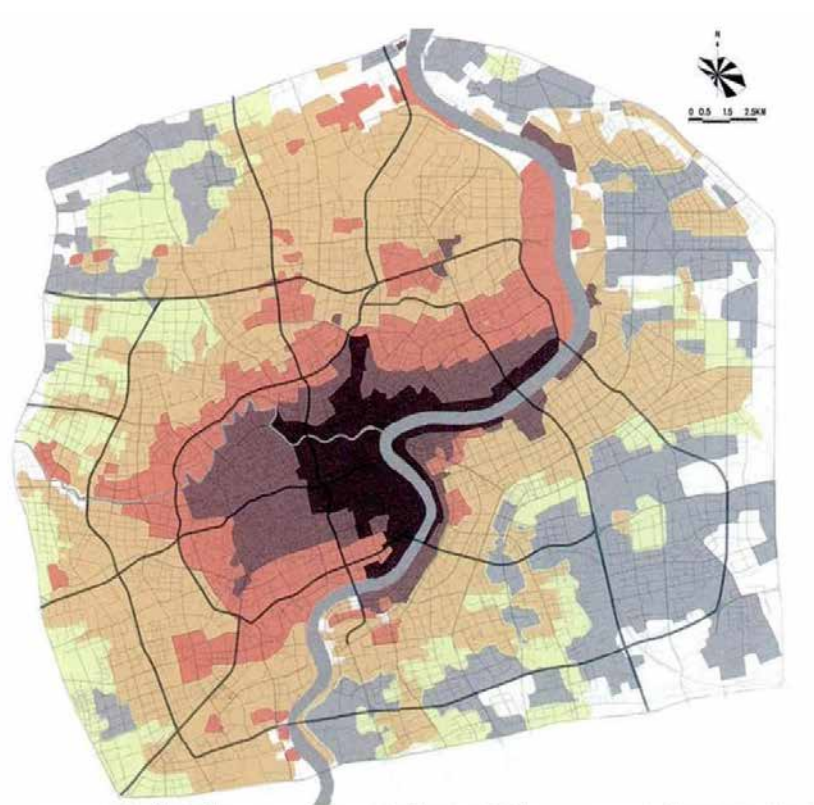
1.9.2 Social & Economy Problem

- **The property company's management and maintenance level of the community has declined, which has conflicts with the owners.**
The property company's management and maintenance level of the community has declined, which has conflicts with the owners.
In the process of maintenance and regeneration of the old public houses, neighborhood disputes often occur due to uneven funding allocation or occupation of open space. Most of the old public houses lack formal property management, and the maintenance level is low.
- **A process of social decay**
After the original occupants moved away, the new workers' estates are soon replaced by less affluent renters who are attracted by the affordability, which leads to a process of social decay and isolation (Yu, T. et al., 2017).
- **Compared with the income of the occupants, high housing prices or rents make them economically unable to afford maintenance costs, which leads to neighborhood disputes.**
- **High demolition and resettlement costs make it difficult to regenerate deteriorated old public houses.**



Fig. 1.32| Photos of problems of New Workers' Estates

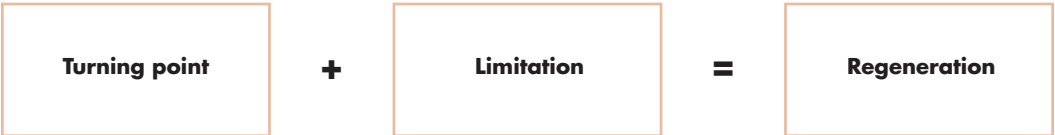
Sources:
<https://feng.ifeng.com/>
<http://news.house365.com/gbk/njestate/system/2019/12/16/029108439.html>
<https://www.stocksy.com/575642/facade-of-old-deteriorated-building-in-poor-slum>



- -1910
- 1910-1950
- 1950-1970
- 1970-1990
- 1990-2000
- 2000-

Fig. 1.33 | The process of spacial developent in center of Shanghai

1.10 REGENERATION OF NEW WORKERS' ESTATES



1.10.1 Turning point

At this moment, the Chinese real estate industry is on the turning point. In the future, it will face two significant trends: from rigid living demand to the quality-improved demand and from the incremental development to the stock operation.

In the housing development of past decades years, rigid living demand housing is the solution to the basic housing problem. There is not much demand for building location, building quality, and the surrounding environment. When the wealth of urban residents has accumulated to a certain level, the need for housing has turned to quality-improved demand.

The past market situation is incremental development, which generally refers to the construction of new land, which is dominated by developers. It is based on the traditional development, and sales model tends to be a short-term profitable business model. The future trend is the stock operation, which is based on the existing real estate. The operator or service provider is the mainstay, and the business activities are mainly based on leasehold use and related services, which are long-term and sustainable. (Hu Huaru, Wang Lizhou, 2017)

The demand mode and the market situation is on the turning point; therefore, the new workers' estates development mode should also be alternative.

1.10.2 Environmental sustainable priority

As Fig. 1.33 shows, the center of Shanghai (inside the outer ring road) is almost completely covered by urban built-up areas before 2000. After that, the urban area developed by expansion to suburban areas. According to the current development mode and demand, the main cities will continue expanding, and even to build a new city. However, from a sustainable perspective and to protect the eco-environment, the city cannot always sprawl.

1.10.3 Regeneration

According to the problems faced by the new workers' estates discussed in 1.9, this type of estate will not meet people's pursuit of high quality of living in the future. They are always located in excellent locations in the city center. Therefore, the new workers' estates have great regeneration value and potential and are necessary to be regenerated (Mah, 2012) (Talen, 2014).

Sources: A Research on the Height Pattern in Shanghai's Overall Urban Design, Zhou Jian, Yu Jing, Chen Yulu, Lu Tianzan, 2017

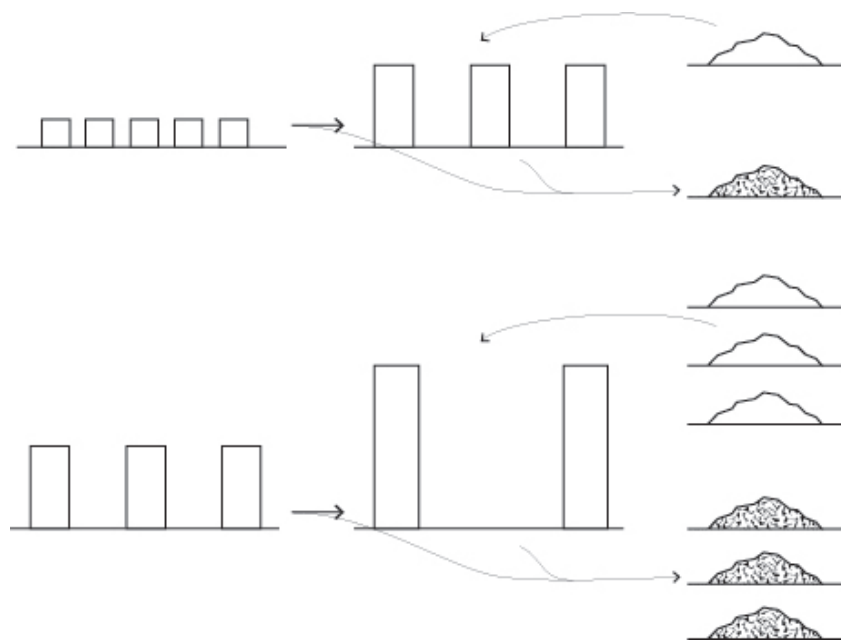


Fig. 1.34| The material flow in regeneration in the past and future

1.10.4 More CDDW in Regeneration

The urban regeneration mode which China is experiencing now is to demolish low-rise buildings and build multi-story or high-rise buildings. According to Chapter 1.4, 1.5, and 1.6, we can know that a large amount of CDDW has been generated, and a large number of building materials have been consumed. These CDDWs and the production of new building materials have a significant impact on the natural environment. At the same time, Shanghai's current capacity to absorb CDDW tends to be saturated, while resource recycling capacity is still in its infancy.

If these new workers' estates are going to be regenerated, the scale of the buildings to be demolished or refurbished will be much larger than the previous low-rise buildings, and the amount of demolition waste will be greater. After the regeneration, to ensure economic feasibility, the scale of the added buildings or newly built buildings will be larger than the original buildings. This means that the amount of construction waste and decoration waste for new construction projects will also be larger, and the number of new construction materials will also be greater.

How to deal with the problem of increased material flow and improved environmental impact caused by new workers' estate regeneration needs to be discussed in later chapters.

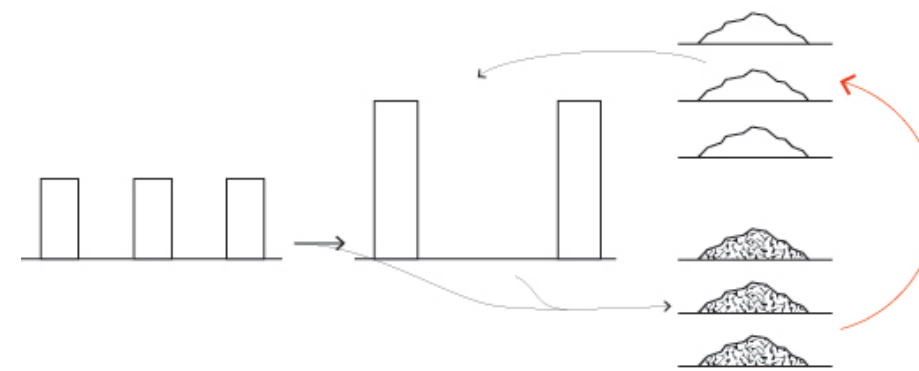


Fig. 1.35| Circular construction material flow

1.11 OPPORTUNITIES

1.11.1 Circular Construction

With the enormous amount of CDDW flow, researchers have realized the importance of the circular economy and have tried to take the first step in circular construction.

The concept of circular construction relates to the circular economy model (Stephan, 2018). Circular construction can be achieved through investigating construction and demolition cycles, finding how the use and reuse of building materials can become the inspiration for new sustainable design schemes and circular buildings. Adapting a circular construction system will help limit the material waste, CO2 emissions, building deterioration.

1.11.2 Circular Construction Techniques

Technically, various methods of recycling building materials have been researched. For example, the bricks demolished from the old building are used as aggregates to produce small concrete hollow blocks. The old concrete can form recycled concrete, recycled cement. The waste wood removed from the buildings can be directly reused or processed into synthetic boards. In recent years, Shanghai has already started to use prefabricated construction, and the application of modular housing is in the research process.

1.11.3 Circular Construction Policy in Shanghai

The willingness to circular construction has been expressed from the policy in Shanghai. In July 2016, Shanghai completely stopped the outward transportation and disposal of CDDW and put forward higher requirements for the resource-based treatment and reuse of CDDW. On January 1, 2018, the provisions of 'Regulations of Shanghai on the management of construction waste treatment' implemented the requirements for classified treatment and full process control of construction waste at the legal and institutional level, and also focused on the city's leading and guiding role in the reduction of construction waste sources and the reuse of resources.

With the significant amount of urban regeneration demand and the aspiration of circular construction, there are opportunities to apply the concept of the circular economy into the process of urban regeneration, to find the possibility of facing new workers' estates regeneration challenges by circular construction.

1.12 OTHER CHALLENGES

There is already plenty of researches on the urban regeneration of low-rise historic buildings, but the regeneration theory and measures for old multi-story residential buildings are not abundant. Following the aim of regenerating the new workers' estates, through the analysis of the current situation, there could be many challenges in the future.

1.12.1 Market

The contemporary urban regeneration mode is demolishing old low-rise buildings (1-4 floors) and rebuilt higher buildings (mainly 6-11 floors). In addition to the original occupants, new rooms are sold to make a profit. In the current market situation, when faced with the renewal of new workers' estates, new buildings need to be built higher to gain benefits. This can lead to greater construction difficulties and may conflict with some urban planning policies (height and FAR restrictions). Therefore, regenerating new workers' estates is more difficult for the development market to obtain profits.

1.12.2 Government

Due to the high land price and housing price of inner Shanghai, the removal compensation is exceptionally high. For example, the first time that Shanghai adopted large-scale monetary resettlement measures in the relocation in 2016, the relocation of Pudong section of subway line 14, 756 residents have been resettled, spends 3.4 billion Yuan, on average 4,250,000 per household(per capita income was 78045 per year) (Shanghai Pudong People's Government). Similarly, finding the space for temporary resettlement residents is also tricky.

Land finance is a unique phenomenon in China in the past two decades. Local governments rely on income from selling land-use rights to maintain local financial expenditure. It has created huge commercial revenue for the Chinese government and provided financial support for urban construction and development. Therefore, regenerating new workers' estates is much more complicated and less profitable than selling a new land.

As the regulator of urban development, how to balance the interests of various stakeholders (developers, origin residents, purchasers, surrounding residents) to maintain social equity is also a big challenge.

1.12.3 Property Rights

The housing property rights problem is complicated in China. The current policy is that residents own the house but only have a right to use the land for only 40-70 years, as the policy has not been expired, how to deal with changing or renewing the contract is uncertain. The uncertainty and complexity are significant challenges for future renewal.

1.13 PROBLEM STATEMENT

Within recent decades urban redevelopment state of Shanghai, a large number of urban areas are redeveloped by densification. Since the 1950s, the new workers' estates have been the primary type of residential areas which replaced the shanty towns and rural villages.

However, the new workers' estates having been built for 30-70 years are tending to have deteriorated physical problems and socio-economic issues. As the Shanghai Municipality has renewed the buildings and infrastructure of some new workers' estates, what needs to be regenerated in the future most seriously is the public space. The general problems can be summarized as low quantity, quality, and usage of public space. A more severe problem peculiar to the public space of new workers' estates is the adaptation to the elderly. Under the trend of climate change, the hard impermeable pave and lack of open soil make the water management of the public space unsustainable.

With the development of the economic level, people are pursuing the improvement of living environment. Public space that cannot meet the demand of living quality will lead to the replacement of original residents by less affluent residents, which will accelerate the decay of the estates, resulting in a larger number of demolition and new construction. The current regeneration mode of regeneration has already generated a large amount of CDDW. When regenerating the new workers' estates, the amount of CDDW and building materials involved will be more considerable. The existing CDDW treatment and new material production have negative environmental impacts and take up a lot of urban space.

Through the regeneration of public space, it can reduce future regeneration demand. By using circular construction methods, the regeneration process can reuse and recycle the CDDW, use bio-based materials and new building technologies. These will make the regeneration of new workers' estates more sustainable and adaptable to future development. Therefore, there should be research on how to apply the circular construction to the regeneration of public space on a small scale. Meanwhile, the application of circular construction will influence the material flow on the urban scale. There can be a circular construction network taking the new workers' estates as the starting point, which need the guidance and strategies to ensure the efficiency and feasibility of the circular process.

2

METHODOLOGY

Research Question

Research Aims

Conceptual Framework

Proposed Research Approach

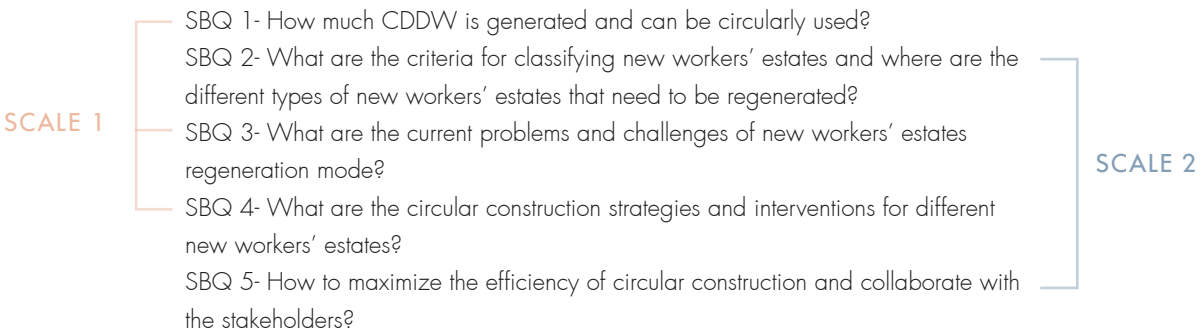
This chapter presents the research problem, aims, relevance, conceptual framework and methodological framework of this research. The purpose is to describe the research method from the current urban development mode to the new urban regeneration mode based on circular construction. The research question is a hypothesis based on the problem field and combined with the existing research methods. Through the whole research to verify whether it can be achieved. Started with a generalization of knowledge and practical gap, this chapter indicates the required concepts and methods of the research, clarifying the parallel between research questions, design methods, and expected outcomes.

2.1 RESEARCH QUESTION

2.1.1 Main research question

How can the CDDW generated during the regeneration of new workers' estate be circularly used to make the public space more sustainable and adaptive to future changes?

2.1.2 Sub research questions



2.2 RESEARCH AIMS

2.2.1 Knowledge gap

Low-rise → Multi-story

The existing development mode researches focus on how to demolish the low-rise urban area and restructure into higher urban areas. When facing higher urban areas, like the new workers' estates, having more than 5 floors, there are not systematic researches and theories to regenerate them sustainably. The large number of buildings that cannot adapt to future urban development will become a massive amount of material and spacial waste.

Since most new workers' estate does not have significant cultural and historical value, especially some of them even have safety risks, the renewal of these buildings has only a small retention value, which is different from the existing urban renewal theories and methods.

Techniqal and policy research → Practical application

There are already many studies on sustainable regeneration and circular construction techniques of high-rise buildings, showing that the technology has been able to increase the circularity rate of demolition and construction waste to a high proportion. Besides, the government has also gradually introduced some policies to support circular construction in recent years. In fact, China's current circular construction rate is still shallow. There is a gap between the technical and policy research, and the practical application.

Impact on single building → Public space & Spatial impact

What's more, in addition to the influence of circular construction on a single building, the spatial impact of applying circular construction to neighborhood scale public space regeneration and urban scale infrastructure layout is also a knowledge gap.

Generally speaking, the gap is the research on urban planning and design combining circular construction with new workers' estate regeneration in the context of China (Shanghai).

2.2.2 Aims

- Find the existing physical, social and economical problems in whole, and link the problems with spatial analysis
- Learning the methods and amount of CDDW materials that can be circularly used
- Research on strategies, principles, policies, and design interventions to sustainable and flexible regeneration on multi-scale: estate and urban areas.
- Find the impact of applying circular construction techniques to spatial development patterns, and enhance the relationship between techniques and practical application through a collaborative process.
- Build a circular construction network to combine circular construction with new workers' estates regeneration in Shanghai.

2.3 CONCEPTUAL FRAMEWORK

This conceptual framework section will talk about the ideas that will be explored in the project and how they are related to each other. It is the reflection that led to the design proposal and helps to find the answer to the research question.

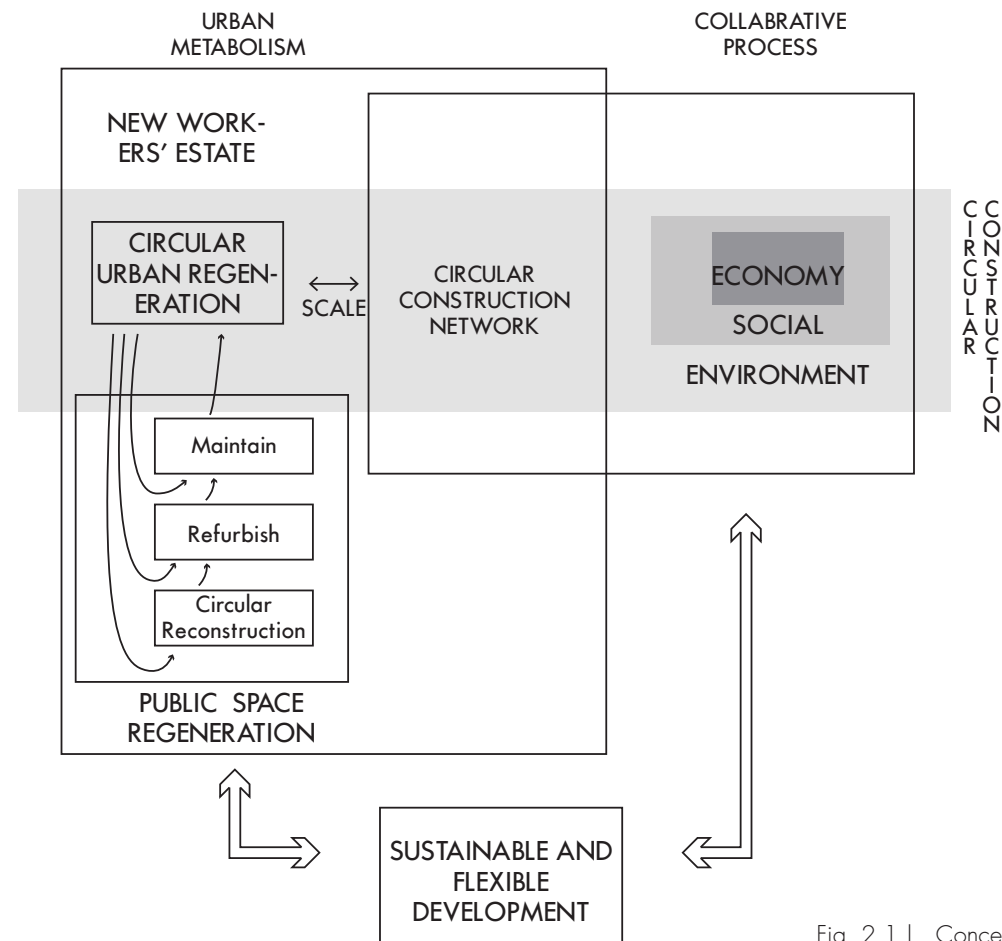


Fig. 2.1 | Conceptual framework

2.3.1 Framework of circularity

The framework of circularity comes from the strong framework of sustainability, as shown in Fig. 2.2. There has always been a debate between weak and strong sustainability. (Neumayer, 2013) Weak sustainability is the idea within environmental economics, which states that human capital can substitute natural capital. Contrary to weak sustainability, strong sustainability assumes that human capital and natural capital are complementary, but not interchangeable (Ekins, 2003). In this report, the policy decisions and collective actions are more focused on strong sustainability, because right now environmental solutions or environmental stocks of capital are being overlooked and priced out of our society, where they can't compete with the money-driven social or economic decisions. The economy is just one part of our society, and our society is just one part of the larger biosphere and environment we live in. Acting as if that's not true is just burning through our abilities for future generations to live on a planet the way we are.

Related to the whole thesis, the precondition of the circularity system is the ecological environment (Brent, 2008). By analyzing the drawbacks of existing development mode in some American-car-oriented cities, and the current theory of 'two mountains' (Clear waters and green mountains are as good

as mountains of gold and silver) (Jinping Xi, 2017), it comes to the vision of redeveloping high-rise inner city instead of expanding to the natural environment. On the other side, the appliance of circularity in urban regeneration can make a positive impact on the ecological environment and sustainable use on natural resources.

The circularity on social level is mainly about the culture and the relationship of different stakeholders involved in the process. In traditional Chinese culture, people reused and recycled the bricks, tiles, woods, and stones as recorded in <智囊-经物卷八>, 1557.

In the circular process of urban redevelopment, stakeholders like government, developers, residents, relating industrial practitioners, and housing associations play different roles. The circularity of urban regeneration can also solve the social problems, for example, the counter-urbanization, new urban slums, affordable housing, and fair housing problems.

From the economic aspect of circularity, it is an economic system aimed at eliminating waste and the continual use of resources. There are economic benefits of substantial resource savings (Circle Economy, 2019), economic growth (UNEP, 2017), employment growth (WE Forum, 2017), innovation

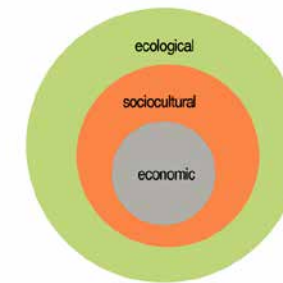


Fig. 2.2 | Strong Sustainable Framework

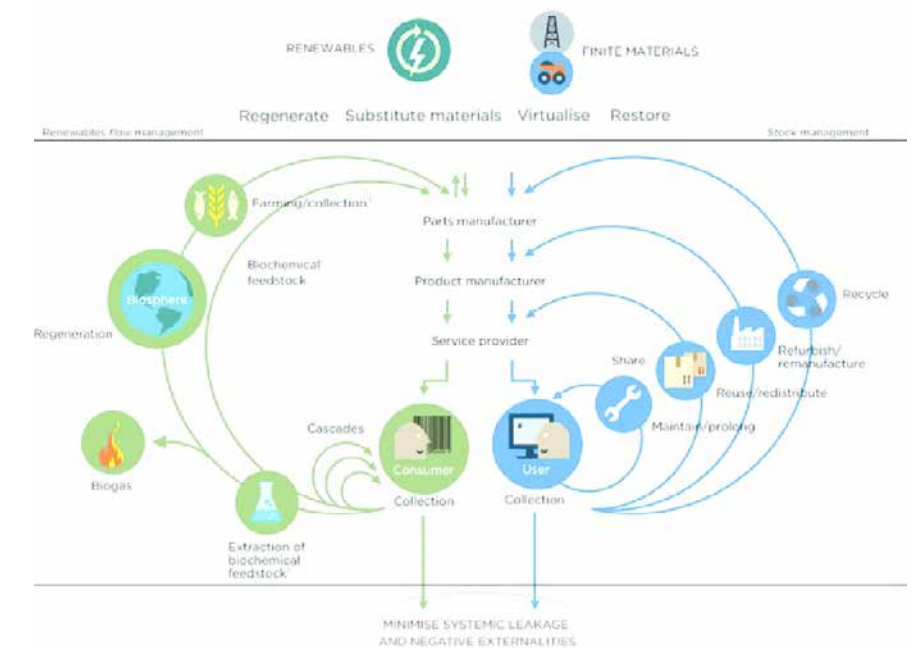


Fig. 2.3 | Ellen Mac arthur circular economy model

stimulus (Kraaijenhagen, Van Oppen & Bocken, 2016) and demand changing (WE Forum, 2017). For the business stakeholders, there will also be new profit, stable material supply, growing demand for services and optimized customer relations (Kraaijenhagen, Van Oppen & Bocken, 2016).

2.3.2 Urban Metabolism

The metabolism concept is a term inspired by biology (Wolman 1965), and applied to an urban context: All of the flows mobilized by the people living on a territory. When it comes to urban metabolism, it combines the circular flows with the physical infrastructure and spatial structure.

The qualitative and quantitative analyses of urban metabolism are only the data research on the resource flows, which demonstrate the data of using, reusing, and recycling of resources in urban development. It is necessary to research these as the first step of research, however, as urbanism research, it is also important to learn where the flows are come from and go to, how to manage the circular flow throw the transition of space. Urban metabolism in the thesis means spatial research under circularity conditions.

• New workers' estate

The founding of New China in 1949 brought the working class onto the stage of history. In order to solve the urgent housing problem, the government began to build new estates for workers in 1951. This is a collective residential area based on public housing and unified distribution according to the distribution system. From the founding of the PRC to the reform and opening up, these houses occupied a very important position in New China. Even after the reform and opening up, it still

has a profound impact on Chinese housing.

• Multi-scale research

The physical organization of resource flow can be expressed in a concise correspondence with provisioning and disposal spaces while the scale of research spaces depending on the flow and geomorphologic context (Designing territorial metabolism, 2018). Certain circularization of flows can be organized on a regional scale, as the flow will need complex processes and massive infrastructure support. While some other progress can also be achieved on a smaller scale with a simplified circuit and within a relatively self-dependent environment.

The multi-scale research related to the project covers from the regional and urban planning scale to the neighborhood and building design scale. In the urban scale, it plans the flow network throughout different types of urban areas in Shanghai. From the regional scale, it organizes the physical and spatial resources of different surrounding smaller cities and the natural environment. To the neighborhood scale, it commits to a new pattern of community which supports the circular material flows more efficiently.

For the building scale, it takes the techniques of how to regenerate every single building into account.

- **Circular urban regeneration**

This concept relates to the circular economy model of Ellen mc Arthur foundation model as shown in Fig.2.3. Their working definition of the circular economy is: "A circular economy is a global economic model that aims to decouple economic growth and development from the consumption of finite resources. It is restorative by design, and aims to keep products, components, and materials at their highest utility and value, at all times." (Ellen MacArthur Foundation & Granta Design, 2015) The general framework of the circular construction is closing loops, hence minimizing the use of scarce or finite materials and preparing current waste for future use.

Corresponding to different high-rise urban area status by analyzing relevant parameters and different circular material use approaches, the circular urban regeneration is divided into three types: maintain, refurbishment, and reconstruction as shown in Fig. 2.4. These three methods have different material flow methods during the regeneration process, but the final space design methods to improve the quality of public spaces are similar.

The whole building is demolished in the reconstruction method. The recycled materials together with the prefabricated, modular, and bio-based materials are used in the new construction process. In the refurbishment process, a part of the original materials are dismantled from the buildings, and they are used again on these housing estates after recycling. The maintain process does not contain the outflow of materials, but uses the recycled materials to help maintain and improve the quality of public space.

The regeneration process relates to a smaller scale of urban area neighborhood and building scale. It mainly involves the design strategies and interventions to regenerate the whole community or simple high-rise building in the most effective, efficient, and sustainable way.

The decisions of where to apply which kind of strategy are made assisted by planning support models. The planning support system (PSS) that facilitates the process of planning via integrated developments is usually based on multiple technologies and common interfaces. PSS contributes to data management, analysis, problem-solving, and design, decision-making, and communication activities. (IGI Global) When simultaneously processing spatial planning combined with multi-criteria spatial features and multiple species material flows, it will be better to use PSS as an aid.

Using the result of the smaller scale strategies and interventions, it can help optimize the larger scale circular construction network.

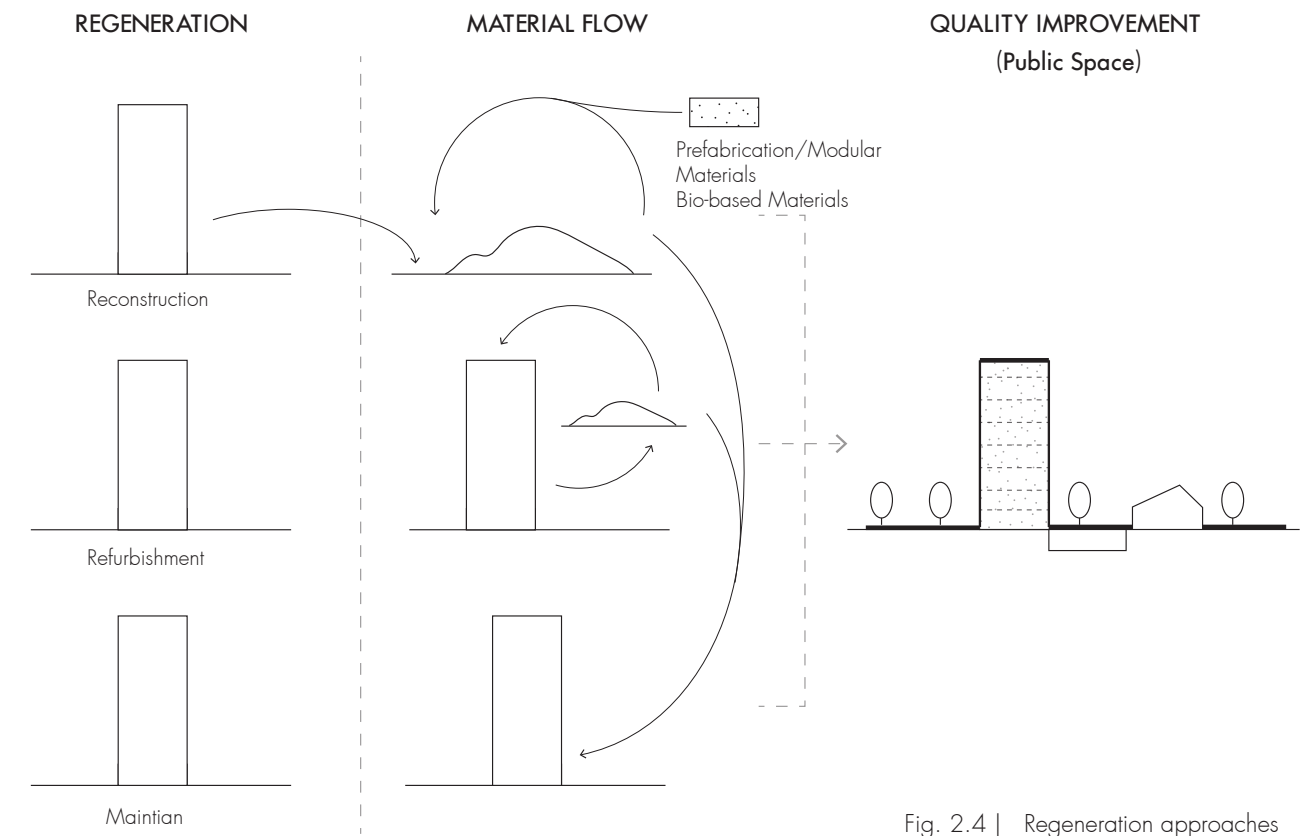


Fig. 2.4 | Regeneration approaches

Because different urban regeneration approaches will generate different amounts of CDDW and form different material flows, the regeneration is divided into the following three types according to the different types of material flow.

Reconstruction (Demolition): Most of the building materials of the original residential area convert to demolition waste. The CDDW generated during the regeneration process enters the circular construction network. Together with bio-based materials and prefabricated modules, these materials will be reused to the construction of new residential areas.

Refurbishment: Part of the building materials of the original residential area convert to demolition waste. The CDDW generated during the regeneration process enters the circular construction network. Together with bio-based materials and prefabricated modules, these materials will be reused for public space improvement.

Maintain: No building material of the original residential area converts to demolition waste. The CDDW from circular construction network, together with bio-based materials and prefabricated modules, will be reused for public space improvement.

2.3.3 Collaborative Process

Collaboration involves people with diverse interests working together to achieve mutually satisfying outcomes.(Natural & Disputes, 1987) The collaborative process can be the key element of collaborative planning.(Purbani, 2017)

Urban planning is not just about the technical process but also about a political and economic process. In the regeneration planning process, except for the redesign of territorial structure, how to organize and balance the stakeholders is in the same position. By collaborating with different stakeholders we can make the planning process more effective, efficient, and sustainable.

The process has a relationship with the social and economic sections of the circularity framework. From the social perspective, the collaborative process guarantees the fairness of the rights of all kinds of stakeholders, balance their respective demands, and promote urban spacial justice. For the economic section, it reduces the cost of materials, maximizes the interests of all parties, and uses this to stimulate the rapid advancement of the urban regeneration process.

The application of the collaborative process mainly contains the strategies and methods together with the geo-design approach to optimize stakeholder collaboration, while also includes policy-making and business model research. The collaborative process of circular construction makes the design goals more implementable and will have further research in Chapter 3 theoretical underpinning.

2.3.4 Circular construction network

In order to achieve a sustainable model, it is important to build a circular development mode despite the urgency to regenerate the urban areas. To solve the urban regeneration issues, circular construction can be achieved through investigating construction and demolition cycles, finding how the use and reuse of building materials can become an inspiration for new sustainable design schemes and circular buildings. Adapting a circular construction system will help limit the material waste, CO2 emissions, future wastescapes, and possibly, overcome the housing crisis.

This concept also relates to the land resource assets involved with the housing and their spatial consequences within construction development. It belongs to regional and urban scales in multi-scale studies. By combining the circularity flows of construction materials, different attributes of spatial resources, and the socio-economy flows, it turns to be the circular construction network.

The classification of different residential areas is done through the evaluation assessment system. Together with the analysis of the future master plan of the city, the new redeveloped centers and sub-centers are determined. Therefore, the areas that will be reconstructed, refurbished, and maintained will act in different roles in the network. With the application of circular construction, there are new facilities and infrastructures being built. Some of the old facilities will also change their functions.

All in all, the circular construction network explains where are the materials come from and go to, how much materials will flow, how is the distribution, storage, and remanufactory change in spatial, who will participate in the process and when will the projects happen.

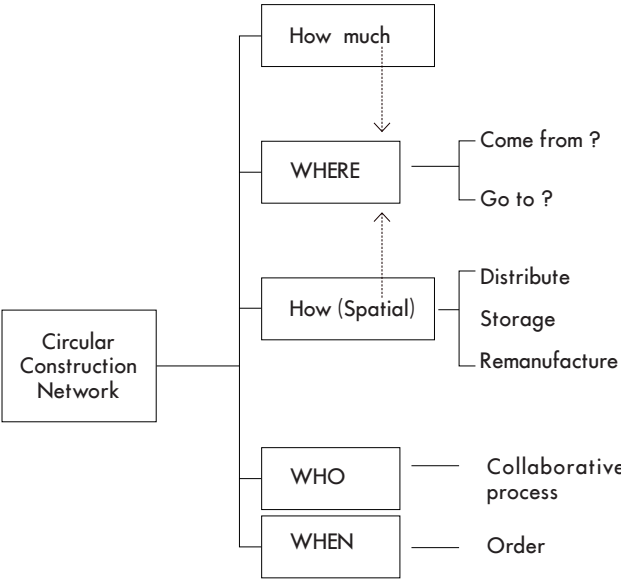


Fig. 2.5 | Circular Construction Network

2.3.5 Sustainable and Flexible Housing

Buildings have a service life. A large number of existing and under construction houses are facing problems of how to deal with them in the future. If they are not properly designed and regenerated, they will become a huge amount of construction waste, which will have a great negative impact on future urban development, society, economy, and environment.

The sustainable housing could have the following features: high using rate of renewable resources and low rate of pollution emissions (Meadows, Meadows and Randers. 2004), from economic and social perspectives, balances the technical aspects of constructing housing with a critical need(long-term economic value) and institutional frameworks (Syn-Consult Africa. 2006). The ongoing economic, environmental, and social costs of physically maintaining the asset and the necessary services that support its residential function must be affordable. To combine with the planning, the location, design and living quality of the asset should reflect perceived value by its market(P Hendler. 2009)

Flexible housing can be defined as housing that is designed for choice at the design stage, both in terms of social use and construction, or designed for change over its lifetime. (Schneider & till, 2005) Some of the flexible housings can be designed to be modular and stackable for serving the growing housing demand and can more effectively address the problems of the housing shortage, some are also designed to attach to existing buildings. (Aakriti, 2018) As the diagram is shown, People's living needs are constantly changing, whether from the quality of living or the location of residence. Flexible housing can save a lot of construction land, as well as building materials and flexible changes to cope with unpredictable future urban development.

In order to ensure the future development of the city, as the research question indicates the final aim is to make the increasing housing more sustainable and adaptable to future changes from both the spatial perspective of territorial metabolism and the social-economic perspective of a collaborative process.

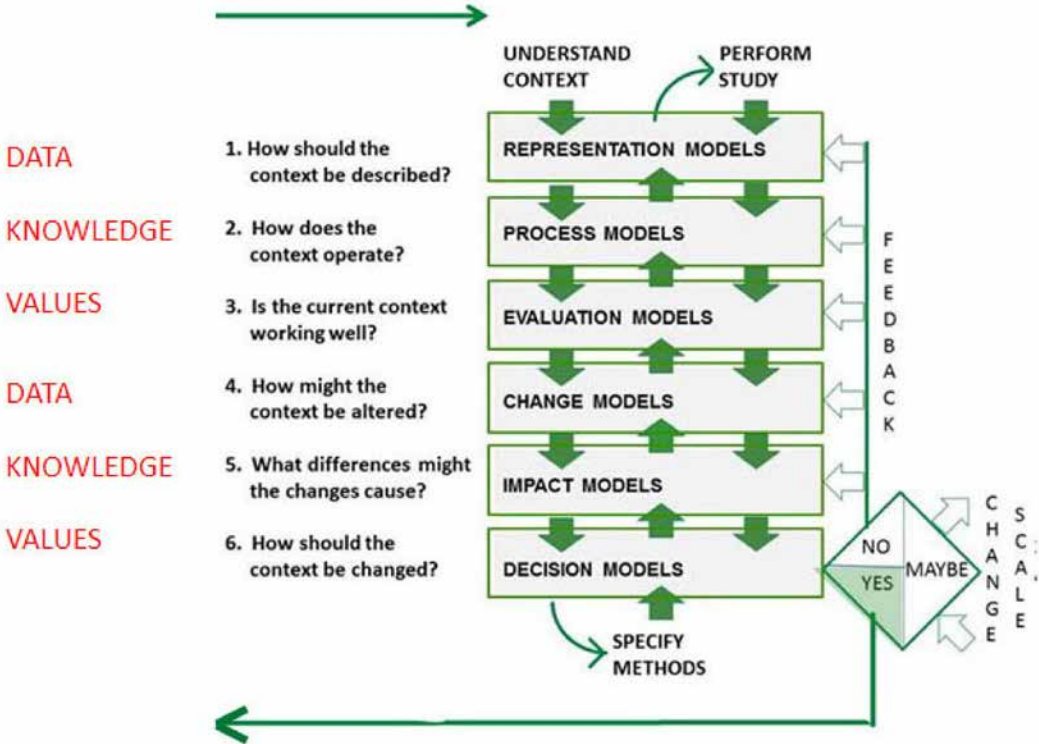


Fig. 2.6 | Geo-design framework (Courtesy of Carl Steinitz)

2.4 PROPOSED RESEARCH APPROACH

2.4.1 Geo-design Framework

The geo-design is defined as "a set of techniques and enabling technologies for planning built and natural environments in an integrated process, including project conceptualization, analysis, design specification, stakeholder participation and collaboration, design creation, simulation, and evaluation (among other stages). (Wikipedia)" Bill Miller defines it as "Geo-design is the thought process comprising the creation of an entity in geographic space".Michael Flaxman, one of the early advocates of geo-design, expands on this definition applied to the field of land use planning. He states:" Geo-design is a design and planning method which tightly couples the creation of design proposals with impact simulations informed by geographic contexts." (Flaxman 2010)

The Steinitz Framework for Geo-design, as shown in Fig.2.6, advocates the use of six models to describe the overall planning (geo-design) process. The first three models constitute an evaluation process that examines existing conditions in a geographical context. The second three models include the intervention process. It looks at how the context may change, the potential outcomes of those changes, and if the context should be altered. The fourth model (change model) develops a proposed change (design scenarios) that is predicted with respect to the science and value-based information contained in the representation model and evaluated against that same information in the impact model. It provides a specific framework for creating. Design in the context of geographic information. (Steinitz, 2012)

The Geo-design framework focuses on multi-scale and interdisciplinary design. Applying design methods or techniques to geographic contexts meets the research aims mentioned above: combining technology with spatial structure, and ensuring the collaboration of the design process by combining multiple stakeholder evaluations. At the same time, the research framework learns from the six models in Steinitz's geo-design framework clearly illustrate from the current situation to the change of the whole system after design. It is suitable for researching the transformations of urban spatial patterns and stakeholders' collaborative relationship after applying the circular construction, providing an integrated research framework for the final circular construction network.

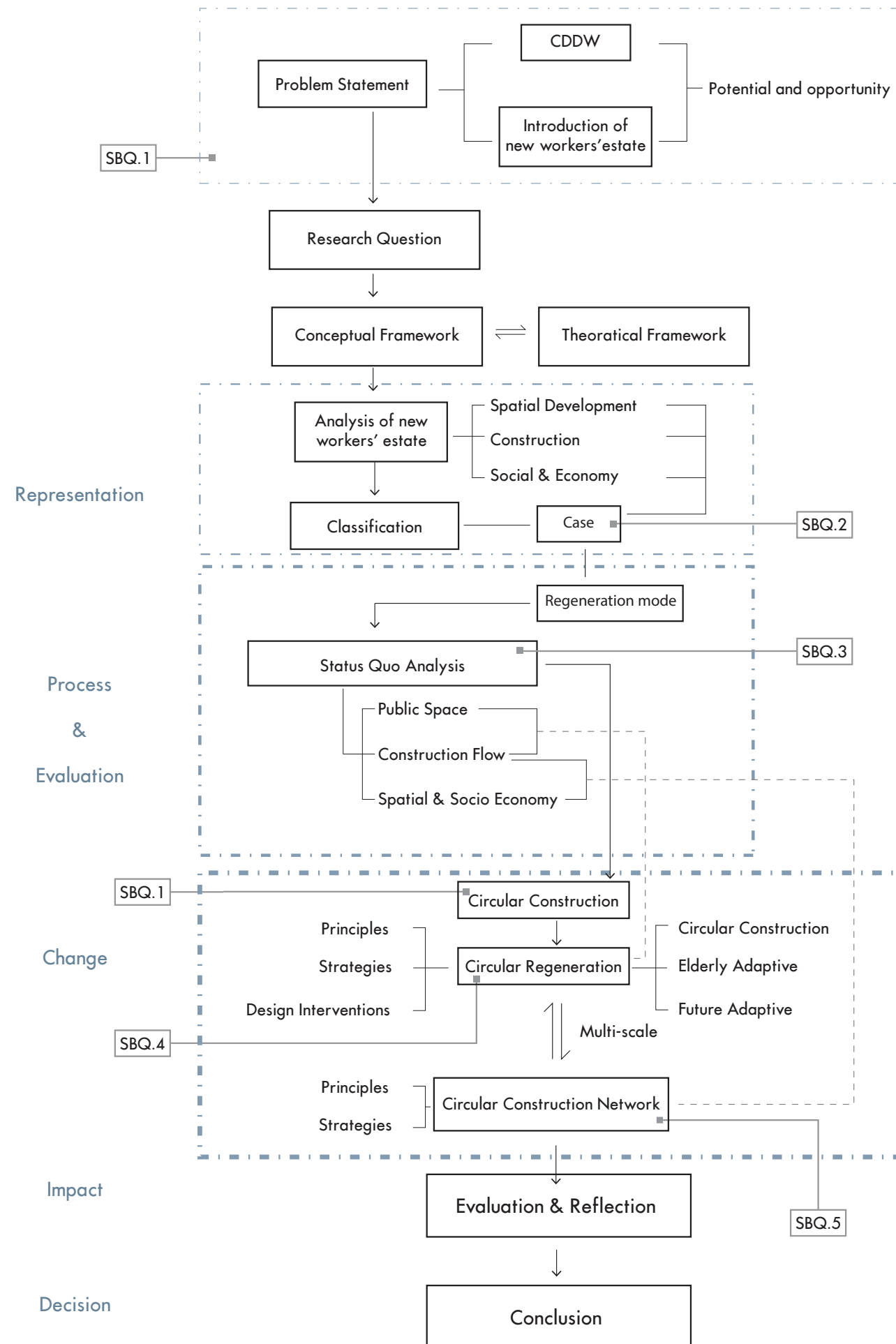


Fig. 2.7 | Methodological framework

2.4.2 Representation

The representation part shows, "How the context should be described?" From the historical spatial development, CCDW generated, physical quality and social-economic issues of existing new workers' estate, find the current problems. **Data collection and mapping** of all new workers' estates and learn the development history of them. Through **case studies**, find examples of different types of new workers' estate and explain the reason why to choose these three types. Analyze the current situation of these cases from spatial, quality, construction and social-economic perspectives, through **fieldwork, literature review, policy study, and mapping**. This will answer the sub-question "What are the criteria for classifying new workers' estates and where are the different types of new workers' estates that need to be regenerated?"

2.4.3 Process

The process part shows, "How does the context operate?" In this stage, use **pattern and process analysis** to learn how are the current regeneration methods work. Through **fieldwork, interview, and literature review**, understand all the current regeneration methods and the material flow generated by existing regeneration. Also, collect the information about the social and economic problems and solutions of the ongoing regeneration. Explain the future regeneration interventions for each type of new workers' estates and make **qualitative analysis** on the material flow. This will answer the sub-question, "What are the current problems and challenges of new workers' estates' regeneration mode?"

2.4.4 Evaluation

The evaluation model explains, "Is the context working well?" which means "Is the existing regeneration method working well?" in this project. Use **fieldwork, investigation, and interview** methods to evaluate the satisfaction of quality improvement of existing regeneration methods and find the unsatisfactory parts. Understand the future regeneration aspiration and demand of residents. Evaluate how much material is wasted during the process by **quantitative analysis**. And also investigate people's views on circular construction. Through these assessments, find the most serious problems that still exist in the new workers' estates and make further analysis of these problems, through **literature review and case study**.

Under the current regeneration situation, the regeneration interventions mainly focus on the improvement of building and infrastructure quality, and the process lacks attention to the improvement of public space quality. This part will further demonstrate the sub-question "What are the current problems and challenges of new workers' estates regeneration mode?"

Existing
Conditions

2.4.5 Change

The change chapter explains, “How the context might be altered?”

Firstly explain the change in circular construction through **literature review** to answer the sub-question “How much CDDW is generated?” Through **literature review and interviews**, learn the methods of how to make the circular use of the materials. By a **quantitative analysis** of waste materials from buildings and secondary materials used for public space regeneration, answering the sub-question, “How much CDDW can be circular used?”

Secondly, refer to **president research and cases**, make principles and strategies for using the CDDW in public space regeneration. The **toolbox** of design interventions will provide different options for different urban areas. **Zoom in** to the refurbishment case for spatial design, following the principle and strategies, and using the toolbox. All the principles, strategies, and design interventions are relative to circular construction, elderly adaptive, and future adaptive. This part answers the sub-question, “What are the circular construction strategies and interventions for different new workers’ estates?”

In a multi-scale, research on what will be the impact on spatial and process after the application of circular construction. Use **spatial analysis, process analysis, data collection, and mapping** methods to answer the sub-question “How to maximize the efficiency of circular construction and collaborate the stakeholders?” after introducing the circular construction concept. Give principles and strategies to the creation of a circular construction network.

2.4.6 Impact

The impact model explains, “What difference might the changes cause?” In this step, use the **impact assessment** to evaluate the impact of circular construction. Use the ratio of quality improvement and material consumption as the evaluation indicator. To assess from which perspectives and to what extent do the circular regeneration interventions enhance the quality of new workers’ estate. By **prediction and data analysis** methods, evaluate how much material is saved through circular construction. Meanwhile, assess the feasibility of the collaborative process and business model.

2.4.7 Decision

The decision part explains, “How the context should be changed?” After getting through this evaluation, if it meets the sustainable& flexible development goal, it can become a method to regenerate the new workers’ estates. Combining with the **stakeholder analysis, business model, and roadmap**, the method researched before becomes more feasible for practical application. The answer to the research question, “Apply the Circular construction network to help make circular use of CDDW generated during regeneration of new workers’ estate for the improvement of elderly-friendly public space quality to make the public space more sustainable and adaptive to future changes” works.

Intervention

Evaluation Conclusion

2.5 CONCLUSION

The methodology chapter shows the main research question and sub-questions, which are explained step by step in the research methodology framework. By studying the president cases and literature review, together with the problem statement, find the knowledge gap to regenerate the new workers’ estates in a practical circular construction method and see the resulting spatial and construction process changes.

The conceptual framework picks the key points from the research question and finds the potential concepts as the solutions to the problem. During this step, find the relationship between circular construction, urban metabolism, collaborative process, and the circular construction network. Explain the reason why choosing these concepts, identify the scope of the study under each concept, and how to use these concepts to achieve the final research aim.

Use the geo-design framework as the skeleton of the whole research. In each model, use different models to answer the sub-questions, and after going through the entire process, to find if the circular construction network can help regenerate the new workers’ estates.

The project consists of two parts, on the one hand, to find the design interventions and research on the material flows of circular public space regeneration. On the other hand, to research on where to use these methods to form a circular construction network.

As the research framework contains complex steps, different scales, and multi-disciplines, use one sample to test if the research process could work well. From the wide variety of new workers’ estates, the most serious, urgent, and complicated old public housing was selected as the research sample- new workers’ estates.

After having a research list of each research model, the next steps are to study the context of this case further first and find two other samples that fit the other two regeneration methods. In the meanwhile, start the design part of Change Model. Then learn the material flow in the neighborhood regeneration scale and get the material flow of large-scale urban regeneration by predictive methods. After that, the research goes to a larger scale to find where else can the circular regeneration methods being applied and finally form the circular construction network.

3

THEORETICAL UNDERPINNING

APPLICATION OF CIRCULAR REGENERATION IN THE SOLUTION OF SHANGHAI NEW WORKERS' ESTATE REGENERATION PROBLEMS

Abstract:

The current urban regeneration of low-rise houses has already generated 180 million tons of construction, demolition, and decoration waste per year in Shanghai. The most urgent need for regeneration in the future is a large number of new workers' estates built in Shanghai from the 1950s. The physical and social decay problems of these areas start to become severe in recent years. Because of the large amount of material flow and the harsh environmental impact, the regeneration mode of new workers' estates should change compared to the current one. Through a literature review of regeneration theories (open building and collaborative planning) and circular construction theory (urban mining), this study describes the strengths and weaknesses of them. Based on this, various theories are also discussed in conjunction with the new workers' estates context. This paper aims to combine the theory of circular construction into the research framework of sustainable urban regeneration, and finds the potential of circular regeneration to redevelop the new workers' estates sustainably, flexibly, and reversibly. It can be concluded that it is possible to face the Shanghai new workers' estates redevelopment challenges by circular construction.

Keywords: Circular construction, New workers' estates regeneration, urban mining, open building, collaborative mining

1. INTRODUCTION

Urban regeneration has been extensively studied for a long time, in order to increase the environmental quality and land values within the limited urban space. Due to the regular pattern of urban development, most of the current urban regeneration objects in China are old, low-rise buildings. With the continuous development of the city, the new workers' estates built from 1950-1990 gradually began to decline. It has already been 70 years since the first construction of new workers' estate in China. Under the regulation (Unified standard for reliability design of building structures, GB 50068) of 50 years of legal design life and the existing situation of physical and social decay, this kind of urban area also needs regeneration. Most of the buildings in new workers estates are 5 and 6 floors, and there are also high-rise buildings over 8 floors. In contrast with the low-rise areas, the regeneration process of new workers' estates is more complex and involves more material flows. On the one hand, the current treatment method of waste materials (Construction, Demolition, and Decoration Waste, hereinafter referred to as CCDW) is landfill, which is already on the verge of saturation. Meanwhile, the large amount of C&DW pollutes the air, water, and soil. Due to the large amount of high-rise housing estate development, it is difficult to withstand large-amount regeneration in terms of environmental and spacial carrying capacity. On the other hand, the regeneration process also needs new materials extracted from the natural environment, causes pollution, and has negative impacts on the environment. Continuously extracting natural resources has caused more severe damage to the environment, which is an unsustainable development mode. For the upcoming new mode of urban regeneration, in order

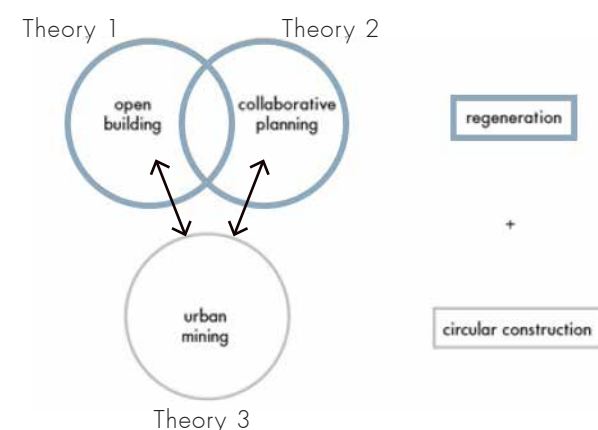


Fig. 3.1 | Theoretical framework of the research

to decrease the waste generation and material consumption, there should be new paradigms and approaches. To achieve this goal, the first step is to reduce the amount of CCDW generated, and at the same time, use the CCDW in the new construction of urban regeneration through reuse and recycle. To reduce the amount of CDDW, in addition to reducing unnecessary waste generated during the construction process through technical means, the method that can achieve this goal to the greatest extent is to reduce the amount of demo-

lition during the regeneration process. Many urban regeneration theories emphasize sustainability. Two concepts-open building and collaborative planning are selected in this article. The open building theory divides the city into different levels, and the service life of different levels is different. Therefore, during the regeneration process, only the parts that need to be renewed can be reconstructed separately instead of being dismantled as a whole, which reduces the generation of garbage and avoids unnecessary waste. The collaborative theory emphasizes the cooperation between different stakeholders and forms a cooperation network among various stakeholders. By obtaining more people's intentions, the rationality of the decision is improved, and unnecessary future regeneration is reduced.

Meanwhile, circular construction, as an extreme aspect of sustainable development, which minimizes the use of construction materials and the impact on the environment, ensures the sustainability of urban development. The circularity is to reuse waste materials and recycle the CDDW through technical methods to new construction. One of the theories most relevant to urban regeneration is urban mining. Urban mining theory considers the artificial materials in the urban area as the stock of secondary materials, and these materials should flow again back to urban areas.

All of these three theories have practice, but the objects of the regeneration theories are mainly low-rise urban areas. Although there are many theoretical and technical research of circular construction, the practice is mainly on large-scale studies, and it is rarely applied to the level of urban regeneration design. When facing the challenges of new workers' estates regeneration, there are knowledge gaps of how to deal with the large amount of CDDW, how to balance the numerous stakeholders, and how to make the urban mining theory efficient and practical?

The reason why choosing these theories is that the regeneration theories can help reduce the waste generation and new material consumption, and the urban mining theory promote reuse and recycle waste materials. Meanwhile, solve the challenges between stakeholders during the new workers' estates regeneration.

These two aspects of the research have high achievements in their respective studies. There is a potential to combine them to carry out more efficient circular use of regeneration construction materials based on reducing the use of them, which has the potential to help a better new workers' estate regeneration. This study aims to focus on the high material consumption problem of new workers' estates regeneration. Through a literature review of the two regeneration theories of open building and collaborative planning, this paper describes their possible contributions to sustainable regeneration. Then, introduce the theory of circular construction to this research. Similarly, through literature review, demonstrate the results and defects of related researches. Contact them in the context of Shanghai new workers' estates regeneration to understand how they can be applied and the shortcomings they still have. Finally, as the theoretical framework is shown in Figure 1, combining the regeneration and circular construction theories to form a new approach of circular regeneration, and demonstrate the possibility that it can solve the new workers' estates regeneration problems.

2. LITERATURE REVIEW OF REGENERATION THEORIES

Many theories are researching on urban regeneration, as linked with the theory of sustainability (Zheng, Shen & Wang, 2014), sustainable regeneration gradually becoming the mainstream research direction in recent years. After screening the regeneration theories, two theories-open building, and collaborative planning that are conducive to a sustainable regeneration framework are chosen. The literature review of this research mainly selects a series of papers by whom put forward each theory, reviewed papers of other people's evaluation of these ideas, and papers that combine these theories with actual projects and with Chinese context.

In the following chapter, the hierarchical, systematic, and multi-periodic characteristics of the open building theory will be mainly discussed. Describe the application of this theory to residential buildings, urban planning, and urban regeneration processes. Based on this theory, the design interventions for different levels are studied.

Although the open building theory involves advocating for user participation, it cannot wholly solve the complex stakeholder problem in the process of new workers' estates regeneration. The regeneration is facing the challenges of how to balance the market-led profit and cost, how to measure the state-led resettlement, and how to solve property rights problems. Therefore, researching collaborative planning theory to demonstrate the necessity of introducing this theory in the process of urban regeneration and the challenges in implementing this theory.

2.1 Open building

The theory began at the Dom-ino house designed by Le Corbusier, which is an open floor plan modular structure. It is a new era of standardized industrial production of housing. A Dutch architect J.N.Habraken put forward the theory of "Support" (Habraken, 1999). He, as the director of SAR (STICHING ARCHITECTUREN RESEARCH), continued to research on the theory of SAR (hierarchical theory, diversity of spatial choices and two-stage supply)(Cuperus, 2003), which has been later linked to open building. The open building theory focuses on the longevity, flexibility, and recyclability of residential buildings.

One of the main viewpoints is the separate system of housing design and construction. There are three separated but coordinated levels of decision making: urban tissue, support, and infill(Cuperus, 2001), as shown in Figure 3.2. The idea is to separate the building components with different service life to reduce the consumption of building maintenance and improve the sustainability of the building. Besides, the open building also emphasizes the idea of users participating in the design process. The advocates believe that the design, construction, and maintenance of housings are the results of the interaction of multiple stakeholders at different levels. It will also enhance the efficiency, sustainability, and resilience of the whole process. (Yang, 2014)

With the development trend from commercial buildings to residential buildings, Kendall applied the open building theory to residential buildings (Kendall, S. and Teicher, J., 2002). Due to the hierarchical, resilient, and periodic nature of open building theory, it is suitable for the research of residential regeneration problems. It enables the redevelopers to reduce unnecessary regeneration steps, systematically control the renewal process of housing, improve the potential of residents' participation, ensure the scientific and effective method of regeneration, and reflect the idea of sustainable redevelopment.

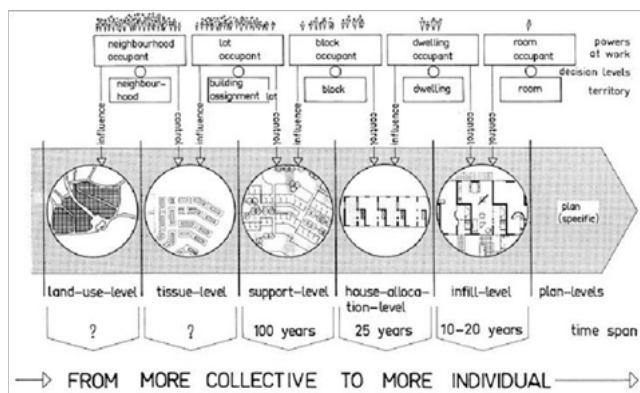


Fig. 3.2 | Decision-Making Levels in Open Building
(Diagram courtesy of Age van Randen)

At the level of urban tissue regeneration planning, it establishes a comprehensive regeneration method from the economic, social, and spatial perspectives, including the built form and spatial pattern, public space, connection with the surrounding environment, place making, and building appearance on eye level. The public space renewal improves the understanding of space making. The urban and regional regeneration plans emphasize the development goals and the value of the surrounding environment. Encourage different stakeholders to participate in the renewal process to establish a collaborative regeneration model to ensure sustainable and healthy residential regeneration.

At the level of building regeneration (support and infill), it contains improvement of diversity, the innovation of residential renewal technologies and methods, enhancement of the quality of regeneration products through industrialization and prefabrication, and modularity (Suo, 2014). In the end, achieve the goal of efficient, sustainable, and resilient residential regeneration.

Taking the open building theory as the research framework, there are different practical regeneration design interventions relate to the three decision levels. Matsumura classified European methods of existing housing regeneration as infill, support, and surface, as shown in Figure 3 (Matsumura, 2002). To sort out the existing housing regeneration methods more systematically, the following paragraphs will classify them according to the three levels of open building.

On the urban tissue level, there are several cases like the Comprehensive Danchi Environment Preparation Program in Japan, the post-war housing estate regeneration in German, and the Main Upgrading Program in Singapore (as cited in Wang, 2016). The methods of regeneration mainly focus on three aspects.

(1) Improve the transportation network of residential areas; divide pedestrian and roadways; promote the development of public transportation; connect residential and urban traffic; arrange parking spaces reasonably; add landscape along the roads.

(2) Improve the quality of public space.

(3) Add public facilities inside the neighborhoods and improve the surrounding public goods of the residential area.

On the support level, the regeneration methods contain additional top floors, partial change of structure and function, upgrade structure and facilities, use sustainable techniques and materials, and embellish the deteriorated outlook of housings through the renovation of the façade (Mikan & Fan Yue, 2009).

On the infill level, the residents can regenerate through improv-

ing the room layout, merging apartments, and redecorate the interior to improve the living quality (Anne, 2016). In conclusion, the theory of open building emphasizing the hierarchical decision making fits the aim of sustainable residential area regeneration from the urbanist's point of view. By summarizing the housing regeneration methods based on the open building 'levels,' the design framework that will be discussed in following chapter 5 based on this theory has the potential to contribute to a more sustainable and flexible housing regeneration.

2.2 Collaborative planning

Although the open building theory has the hierarchy of urban tissue, the theory still pays more attention to the building and community scale research. However, from an urban planning perspective, it is essential to handle the urban regeneration projects under the context of the whole urban or metropolitan scale. In addition, although the open building theory emphasizes participation, the contribution to the technical level is its main advantage. The theory discussed in this section is broader in scale and more collaborative in terms of participatory aspects.

Patsy Healey (Healey, 1996, 1997) developed the theory of collaborative planning for inclusive, environmentally sensitive, and socio-economical urban planning. It is one of the most famous theories under the trend of 'Communicative planning'. Collaborative planning is a new paradigm for urban planning, thinking of it as an interactive process. The process is a government behavior that takes place in a complex and changing situation and it is affected by inclusive economic, social, and environmental sectors (Healey, 2003). It also pays attention to transforming the task of urban planning from the physical spatial design process of the 'building places' to the collaborative process of participating in the "place making" (Healey, 1998). Collaborative planning encourages people to engage in communication with equality and shared information, to learn new ideas from multi-disciplines, to create innovative ideas, and establish systematic solutions towards the aim of place making

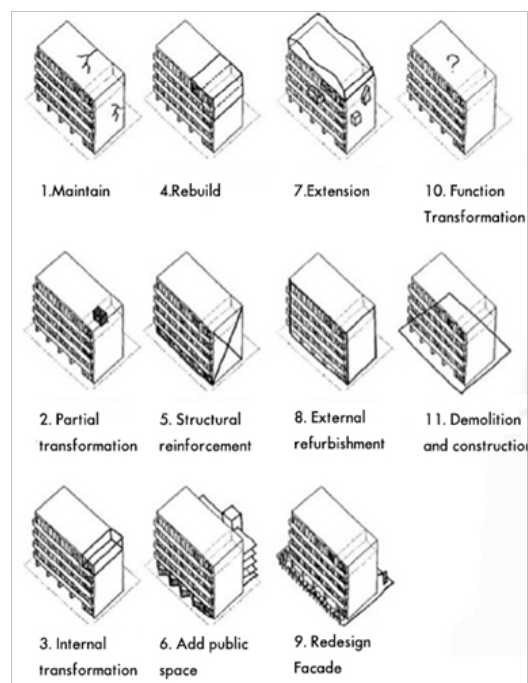


Fig. 3.3 | Summarized method of existing housing renovation in Europe (by Matsumura Shuichi)

(Purbani, 2017).

In contrast to the new housing project, the regeneration process is more complex and relates to more stakeholders. In order to comprehensively and accurately gather the demands and targets of multi-stakeholders, the theory of collaborative planning is necessary.

The regeneration process is centered on residents' participation. Through the improvement of the diversity of residents, the enhancement of the physical spatial environment and the social coherent has been realized. The regeneration under the guidance of collaborative planning achieved sustainable regeneration of deteriorated housing estates and provided useful experience and methods (Suo, 2012).

However, the collaborative planning theory still has some challenges in practice. During the construction process, the stakeholders always have their personal interests. When planning collaboratively, it is difficult to achieve the goal due to conflicts of various interests. Collaborative planning is aiming for cooperation under the goal of public discourse win-win, while the power of it is too limited to affect the choices of individuals and groups. Meanwhile, this theory puts professional planners and the planned in an equal position to communicate, which is a challenge to planning professionalism and authority (Allmendinger & Tewdwr, 2002).

3. LITERATURE REVIEW OF CIRCULAR CONSTRUCTION THEORY

The circular construction theory contains waste minimization, resource recovery, materials recycling, and urban mining (Cossu & Williams, 2015). The following chapter describes the development history of urban mining from metal materials to other building materials. It shows the disadvantages of the application of urban mining to single buildings and the material flow process at the urban or regional scale.

It is not enough to only have a large-scale theoretical foundation. Since the regeneration of new workers' estates are mostly neighbourhood-scale designs, based on understanding how materials flow in urban and regional scales, the methods involved in small-scale circular construction are summarized.

3.1 Urban mining

The theory of urban mining (UM) was first proposed by Urbanist Jane Jacobs half a century ago (Xue, 2018) she noticed that the city itself had become a new raw material mine. 'As construction time increases, the city will become more vibrant and more productive (Jacobs, 1969). It is one of the circular construction theories which emphasize the circular flow most. After this, due to the original meaning of mining, the rapid industrial development, and the scarcity of metal resources, the theory was developed mainly to describe the metal material recycling from anthropogenic stocks.

The theory of UM has been extended to a circular use of anthropogenic material in the urban area, as the stock of raw materials does not only exist in landfills but also has flowed to buildings and infrastructures (Brunner, 2011). It went further to all the processes of circular substance and energy flow from urban metabolism, as shown in Fig. 4 (Baccini & Brunner, 2012).

However, the application of UM for the single building has some difficulties. The service life of buildings is long (some buildings are even of cultural protection value and will not be dismantled), so the cycle period is long; the buildings are

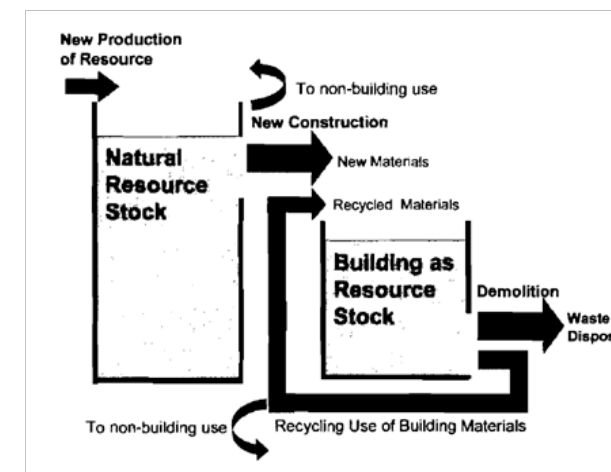


Fig. 3.4 | Diagram of metabolism of material use around buildings (Arora et al. 2019)

relatively scattered, which is more difficult to be recycled systematically than other infrastructures; the materials of buildings are challenging to be separated which causes the high cost and low efficiency of recycling (Koutamanis, van Reijn, & van Bueren, 2018).

From the perspective of the city scale, the larger the community is, the more suitable it is to discuss the application of UM (Huuhka & Lahdensivu, 2016). In this scenario, a large number of buildings provide sufficient reserves for secondary materials. Through the overall coordination, the scattered resources can be rationally allocated. Industrial separation, transportation, and remanufacturing have also become efficient and profitable so that materials can be recycled. Therefore, for urban-scale planning, UM is a practical theory for implementing the recycling of building materials.

The two additional aspects mentioned by Brunner based on others' research indicate that UM is different from the simple reuse of urban building materials and is a necessary step to specialize in the flow of urban metabolism. The first one is to create a knowledge base containing the data of the whole lifetime flow of materials (Brunner, 2011). The knowledge-base shows the types of materials, the flow, the stocks, and the recycling process, which, as an information basis, supports the decision making. The rich data support makes UM better than reuse in more systematic and efficient recycling of materials and maximizes the value of materials. The second aspect answers the question of 'where recycling takes place'. The additional infrastructure required for the intensive recycle process is located. Locating the facilities of the UM process and balancing the spatial layout in urban areas creates the connection between UM theories and spatial impact (Brunner, 2011). The issues to be considered in planning this location are (1) the relationship with secondary material generation position, use position, storage position, (2) energy consumption, and economic cost during the transportation and manufacture process. Additionally, different areas with different characteristics will act in different roles (input or output) in the material flow network.

3.2 Circular construction approaches

The UM theory reviewed above is more like a large-scale model that focuses on flow data calculations and large-scale (international, national, regional) geo-design. There is a lack in the discussion of the small-scale transitional spatial patterns under the impact of urban mining. Under the key thought of the recycling use of construction materials, there should be more circular construction planning and design interventions.

What needs to be emphasized is that the design interventions on a small scale are not a separate and independent circular construction, but a small-scale spacial design based on large-scale urban mining flow.

There are some examples of small-scale circular construction approaches. Several design organizations or companies like Metabolic, BAMB (Buildings as material banks), Urban Mining Collective, Rotterdam circular, and SUPER LOCAL have already experimented on circular construction practice.

The technology of recycling and the materials that can be circular used are progressing. The first step is the circular use of building components such as window frames, doors, and inner walls (Metabolic, 2018). With the development of techniques, the aggregates can be reused for infrastructure and then for buildings (Rijkswaterstaat & RIVM, 2015). Recently, the project Restructuring Bleijerheide Kerkraede done by SUPER LOCAL-Super circular estate uses the material of the existing flats when constructing new houses. Two complete apartment modules were lifted from the original building to be the basis for two circular test houses (Circulaire woningen).

During the circular construction process, in addition to circular flow like UM does, it also pays attention to circular construction approaches, like prefabrication, modular, and reversible building design. These thoughts emphasize new construction techniques to make it easier for dismantling and waste separation. With these techniques, the demolishment of existing buildings is more efficient. Without complex separation, the prefabricated materials and modular modules can be reused easily, which increases the efficiency of urban mining.

4. APPLYING THE THEORIES TO NEW WORKERS’ ESTATE

These three theories have some applications in the process of urban regeneration in China. These combinations are more suitable for the past low-rise urban regeneration mode, and there are still some challenges in the future new workers’ estates regeneration. But they are still necessary as the knowledge base for transforming a more sustainable regeneration. Only combining them and analyzing together with the problems faced by the new workers’ estates regeneration in Shanghai can better serve future regeneration.

Open building

Some scholars in China have studied the Japanese SI (Support and Infill) housing system developed from the open building theory. They rely on the research framework from Japan and link it with the Chinese background. The separation of the support and the infill achieves the integration of current needs with long-term transformation, the unification of public interests and individual needs. Recently, it has achieved rapid development in China and has become an important target product for the development of construction industrialization and residential industrialization (Li Zhongfu, 2019). The most obvious change is the substantial increase in newly built prefabricated buildings, which are pre-produced separately in terms of building structure and infill parts.

Collaborative planning

The implementation of the collaborative planning theory is alternative in different contexts. To combine it with the context of China, there are specific challenges. Although China’s community regeneration planning is still in its infancy, the focus point has already started to change for quality improvement

compared with previous rapid incremental planning. The planning value orientation of the physical space and the allocation of infrastructure is not out of the government’s blueprint but from the perspective of social justice and public demand (Jiang Shanhong 2016).

There are inevitable disconnects between western planning theories and Chinese practice. On the one hand, low-income community residents do not have enough social resources and channels to participate in the planning process and express their interests; on the other hand, Chinese planners are still representatives of technical forces. In the process of transition from technicians to social coordinators, coordination methods and techniques are still in their infancy, and the ability to mobilize social resources for collaboration needs to be improved (Yuan & Chen, 2015). Due to the differences in socio-economic development and construction conditions in China, the types of urban and rural communities are diverse, and the modes of collaborative planning are in varied forms. Lastly, the time consumed by communication has a conflict with rapid development.

These do not prevent collaborative planning from being a theory applicable to urban regeneration. However, these problems need to be solved in combination with other theories in the future of residential area regeneration in China.

Urban mining

Current urban mining in China refers to the recovery of resources from waste metals, waste plastics, waste rubber, and other materials produced in the process of industrialization and urbanization (Hu & Poustie, 2018). In the past few years, urban mining demonstration base construction (UMDBC), a large-scale urban mining project hosted by the government, is also about these resources (Xiaofei et al, 2017).

Urban mining for building materials in China is more inclined to ‘informal collection’ (Scheinberg, 2011). There are private sectors such as individual business and private enterprises engaged in the collection, classification, and sales of C&DW. The materials contain concrete, rebar steel, brick, furniture, doors and windows. The government-led construction material treatment method is mainly a linear process, while the private market-led urban mining is small in scale. Without the assistance of extensive facilities, the process is dispersed, and the total amount and efficiency of recycling are low. With the development of urban mining techniques and awareness of government, there is a growing potential for applying urban mining to construction material in China.

Necessity

The reason why it is necessary to apply the theories to new workers’ estates is that the new workers’ estates regeneration will suffer severe environmental impact of CCDW, which means methods that can reduce, reuse and recycle the waste is necessary for the future regeneration. Therefore, open building and urban mining theory are applied.

As the regeneration is led by the government and mainly implemented by market-led companies, it is hard to balance the cost and profit between stakeholders. The property rights of the new workers’ estates are multiple and complex. It is difficult to reach a unified regeneration intention across the entire community or even one building (Liao & Bao, 2014).

To decrease the construction material and environmental impact during the regeneration process, we should minimize the quantity of regeneration construction. Unlike the fully demolition and reconstruction mode of low-rise buildings, demolishing all the new workers’ estates is not a sustainable plan. Evaluate the old estates, only the areas with structural safety hazards or severe social decay shall be demolished.

For those new workers’ estates that have the potential to retrofit, apply the two regeneration methods mentioned above for redevelopment. The application of open building theory splits the residential regeneration process into different levels. As different parts of a housing estate have various service lives, the separated renewal of each part maximizes the use of construction materials and avoids unnecessary demolition waste. The collaborative planning, then acts the role of organizing different stakeholders involved in this process, to balance and maximize the benefits among these sectors. Simultaneously, during the process, considering more aspects of all the stakeholders, the planning results can meet the expectations of more people. In the future, the risk of frequent demand for regeneration because of the inability to meet particular needs and the constant discovery of new problems is less. This also improves the efficiency, effectiveness, and validity of new workers’ estates regeneration.

With these methods, in the process of urban regeneration, although the amount of construction has been reduced and the material utilization rate has been increased, a large amount of construction materials are still wasted. Therefore, more theories and methods are needed to support more sustainable new workers’ estates regeneration in the future. Meanwhile, the practical application of urban mining is not as good as expected. The next step should be a more comprehensive study combining theories that can solve the problems in the actual regeneration process.

5. CONCLUSION: THE POTENTIAL OF COMBINING CIRCULAR CONSTRUCTION WITH REGENERATION

To sum up, the comparison of these three theories about their scale, contribution to circularity, the gaps and their current application in China is as shown in Tab.1. They have different contributions to the circularity and regeneration, but each of them has shortcomings and the application in China just started.

	Scale	Circularity	Gaps	Chinese application
Open Building	From infill to urban scale	Reduce	Impact on urban fabric	Prefabrication building
Collaborative Planning	From community to urban scale	Reduce	Combine with complex context	Initial stage
Urban Mining	From urban to regional scale	Reuse and Recycle	Small scale design interventions Practical application	Large scale research

Tab.1. Comparison of the three theories

To sum up, the comparison of these three theories about their scale, contribution to circularity, the gaps and their current application in China is as shown in Tab.1. They have different contributions to the circularity and regeneration, but each of them has shortcomings and the application in China just started.

Considering the ‘waste as resource’ characteristic of circular construction, the solution of new workers’ estates regeneration material waste can be the application of circular construction. Through the analysis of the existing regeneration situation,

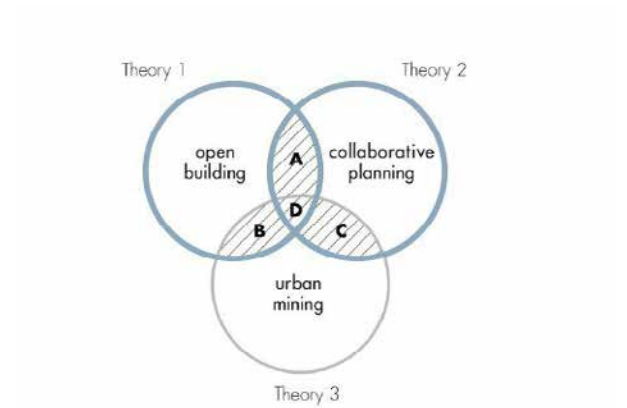


Fig. 3.5 | Combination of the theories

there are mainly two categories of circular regeneration. One approach is refurbishment instead of fully demolition, to renovate, repair, renew facilities and improve the quality of public spaces in existing estates. During this process, according to the theory of urban mining, the old deteriorated parts are dismantled and recycled. Then use the circular materials to replace the old deteriorated parts in turn. The other approach is for those estates which have to be demolished. When reconstructing them into new urban areas, consider the sustainable and flexible goal. The new construction should use the prefabrication and modular construction methods, which is reversible for future circular regeneration.

These two circular regeneration approaches can play a better role combining with the regeneration theories: open building and collaborative planning. The open building theory mentioned above is a sustainable approach to regeneration. Regenerating only the parts that need to be refurbished significantly reduce the construction materials required. Replace the materials that are still needed in the regeneration process with circular construction materials, which significantly reduces the environmental impact.

The theory of collaborative planning and urban mining promote each other. The regeneration process of new workers’ estates has difficulties with the market and government. The low profit and high workload are obstacles to urban regeneration. By circular use of the construction materials, the deteriorated buildings can play an extra value. With the collaborative organization with the stakeholders, we can make a business

Combination conclusion

In conclusion, the potential of combination of the three theories is as shown in Fig.5. Part A is the interaction of open building and collaborative planning, as they all emphasize residents participation during the regeneration, which makes the regeneration result meet the expectations of most people, balance the interests, promote the desire of urban regeneration, and increase the success rate. The combination of urban mining and open building (part B) means reducing the CDDW generated by urban regeneration while reusing and recycling the CDDW. When both theories are applied at the same time, the waste and their impact on the environment are reduced to a greater extent. The urban mining is a material flow on a city or even a regional scale, involving many stakeholders. To make sure the urban mining is efficient enough, it can be combined with collaborative planning to form a collaborative network. Only in this way can the efficiency and economic benefits of urban mining be improved, so that it is no longer a theoretical study, but has practical feasibility. All in all, the part D means the final circular regeneration combining all the three theories. This can reduce CDDW, at the same time, efficiently reuse and recycle the waste, balance the stakeholders, and promote the urban renewal desire of residents, developers, and governments. It means that, the combined circular regeneration has the potential to solve the material waste and complex process problem.

mode. The cooperation between government and social capital was originally a project operation mode in public infrastructure. Under this model, private enterprises are encouraged to cooperate with the government and participate in the regeneration of new workers’ estates. In addition, the circular regeneration can also be combined with the Internet + model. Make use of the Internet platform to give full play to the optimization and integration role of the Internet in resource allocation. Let the Internet and circular regulation integrate to improve redevelopment efficiency and potential. There are two main aspects that this research can be further improved. The first one is to grasp the quantity of circular construction materials in practice. Secondly, for the approach formed by the combination of the theory review of the literature, a new toolbox can be formed by further induction.

6. DISCUSSION

In this paper, the research turns from the current low-rise redevelopment mode to the regeneration of new workers’ estates, with the aim of sustainability. Through the literature review of selected regeneration theories (open building and collaborative planning), use them under the context of Shanghai new workers’ estates. In order to further reduce the construction materials needed for regeneration and the impact on the environment, this paper also reviews the theory relates to circle construction. The conclusion is that circular construction combined with the regeneration framework for open building and collaborative planning is a feasible solution of new workers’ estates regeneration problems. The result can be used in the future regeneration of a large number of new workers’ estates in China. The theory of open building and collaborative planning have common points, while in this paper, the review focuses on expressing different research aspects of them, the one emphasizes the regeneration technique, and the other one concentrates on the regeneration process. With the support of a large number of researches on circular construction technology, further study on the multi-scale spatial impact of circular construction is the issue that urban planners should pay attention to. Instead of discoursing urban regeneration theory or circular construction theory separately, based on understanding the two parts, analyze the potential of the two for sustainable redevelopment, and look for the possibility of combining them to make the combined method play a more significant role. The future development prospect is that more and more new workers’ estates are entering a decline period. To solve the physical and urban decay problems, large-scale regeneration is inevitable. The further development of the circular construction combined regeneration approach under the context of China can also relate to the PPP (Public-Private Partnership)

4

REPRESENTATION ANALYSIS

Current status and three types of new workers' estates

This chapter is a description of the context of new workers' estate. It includes re-researches on two scales. Starting from a large scale, learn and summarize the background information of the distribution of new workers' estates in the city, the spatial form of the new workers' estates neighborhoods, and the typical interior layout of it. Classify the new workers' estates into three types by case study. Learn the status quo of this estate. Because of the research approach is to predict the amount of flow in urban scale through the flow in a single unit area. After the research in this chapter, we have a basic understanding and classification of the new workers' estates as a whole and the background information of the selected case. Finally, get a deeper understanding of the site with fieldwork.

4.1 DISTRIBUTION AND STATUS QUO OF NEW WORKERS' ESTATES

4.1.1 Distribution in Urban Scale

The data of all the residential estates in Shanghai were obtained through the Real Estate Administration of Shanghai Municipality, and the distribution is shown in Fig 4.1. The number of residential estates in the inner ring road of the city tends to be saturated, especially Jing'an, Putuo, Hongkou, Changning, Huangpu, Yangpu, Xuhui, Pudong districts have become concentrated areas for real estate development due to superior location conditions. As the distance from the city center increases, residential areas are mainly distributed along major transportation lines, and more concentrated near the station. The spatial structure of traditional residential areas concentrated in the city center has been changed. The heterogeneity of the central urban area is mainly manifested in the coexistence of old and new estates. Since the 1990s, the residential market in Shanghai has continued to develop, and the regeneration of the old area has become an economic behavior of developers under the guidance of the government. For developers, the urgent issue of living quality is not their main concern, but maximizing profits is their ultimate goal. The area that is in urgent need of regeneration are often areas with high living density, poor living conditions, high cost of regeneration, and low economic benefits. Therefore, the regeneration of old areas is not carried out according to the degree of poor living quality, there are still old residential estates in urban centers. The newly built residential estates also have different styles, forming a variety of living forms, and the overall quality of various types of housing such as high-rise, mid-rise, multi-story, low-rise high-density, town-houses, and villas has been significantly improved.

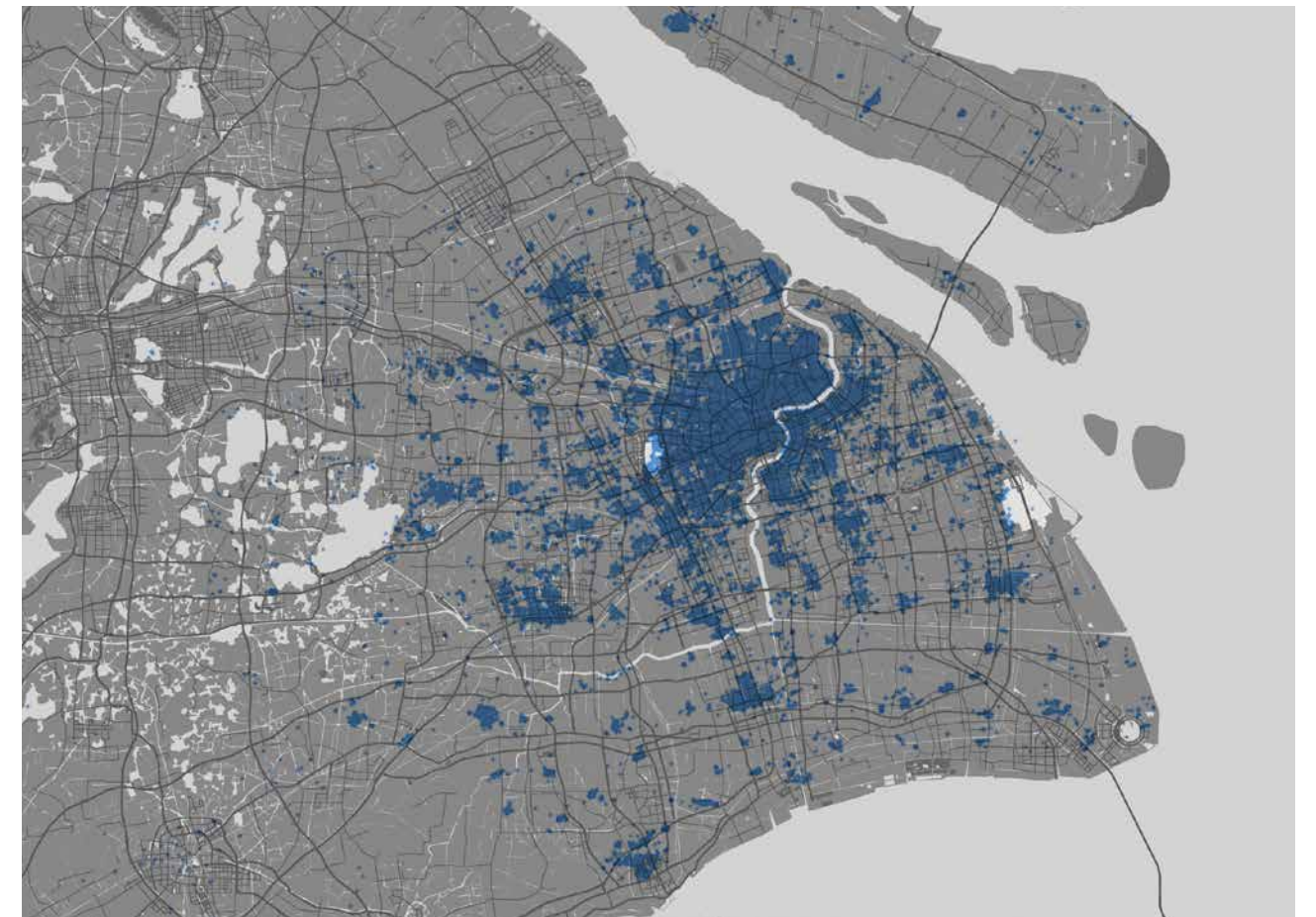


Fig. 4.1| All the residential estates in Shanghai



Fig. 4.2| All the new workers' estates in Shanghai

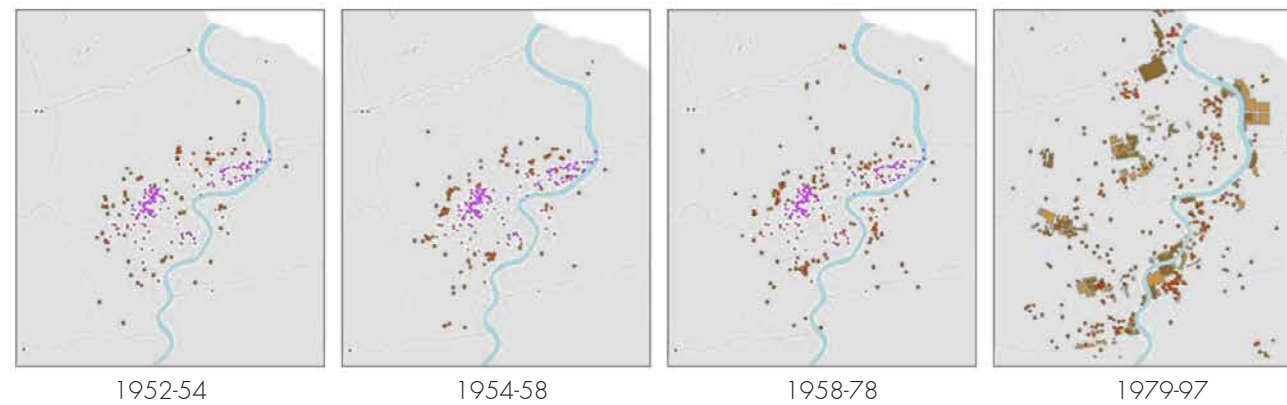


Fig. 4.3| Historical development of the new workers' estates in Shanghai

The naming of New Workers' Estate has a significant feature. The name usually includes the words 'Village' or 'Yuan.' Therefore, from the database of all residential estates in Shanghai, by filtering the name and adding the indicators of building age, the number of floors, and the size of the settlement, all new workers' estates were chosen. The location distribution is shown in Fig. 4.2.

In the 1950s, the solution to the housing difficulties of workers was not to start with the reconstruction of the old downtown area at that time but to choose a relatively remote suburban industrial area for redevelopment. The location of the new workers' estates are always closer to the factory, and even the location of some new factories at that time already considered the new workers' estates. The living place is close to the workplace, and it also blurs the boundaries of work and personal life. At the same time, because it is difficult to use the existing infrastructure in the central city, the public service facilities in the new estates are relatively complete, providing almost all the necessary living facilities for residents,

which also objectively promote a type of new life. (Liu Yong, 2011) The living quality of new workers' estate is superior to the shanty towns and worse than the modern estates in terms of construction quality and usage age. The high cost of regeneration puts the new workers' estate in an awkward position in urban regeneration.

The suburban new workers' estates were built in recent 30 years, as shown in Fig. 4.3 and used for a short period, so the physical decay was not very significant. At the same time, the number of all the new workers' estates is large, and in-depth research is challenging. Therefore, in this study, the research scope was limited to 442 new workers' estates within the outer ring road (Fig. 4.4). These new workers' estates located in the fringe area of the central city, and forms a visible "belt" around the inner ring, transmitting the relationship between the original concession and the surrounding poor areas. It creates a specific area of Shanghai residential spacial structure.



Fig. 4.4| New workers' estates inside outer ring road



Fig. 4.5| Satellite photo of typical new workers' estate

4.1.2 Typical Typologies of New Workers' Estate

From the layout of the new worker's estate, there is not much relationship between the building and the natural environment. To arrange as many houses as possible in a plot, the houses are mainly in the 'row' type, arranged compactly, and the in-between space is maintained to meet the basic sunlight requirements. The style of the house is a multi-story brick and concrete building that is convenient for fast design and construction. The form is completely unified. The architectural style of the house is very simple and undecorated (Xiang Xuan, 2011).

The layout of the new worker's estate in Shanghai has experienced a long period of exploration. At the beginning of construction, the 'surrounding' neighborhood layout of the Soviet Union had a significant impact on the planning of residential areas in Shanghai. Gradually people find that this form from the West is in contradiction with Shanghai's geography, climate, and people's living habits. Under the

condition of limited residential investment, the use of natural orientation and ventilation is essential. Generally, we are used to the rooms facing the south side, and the buildings are arranged along the wind direction. The practice has proved that due to the excessive pursuit of the 'surrounding' form, many angles and shadows are generated, which is not conducive to ventilation and sunlight. Therefore, most of the surrounding style estates are the new workers' estates with a relatively long history of construction as an experiment, and those built later are mainly in the form of 'row' type (Fig. 4.5).

The advantage of the row style is that it can make full use of the sunshine in winter, avoid the strong sunlight in the afternoon in summer, and facilitate proper ventilation. One of the most important reasons that the new workers' estates in Shanghai are dominated by row style is due to the strong sunlight in summer. In the afternoon, the rooms on the west side will be exposed to strong sunlight, which will cause the

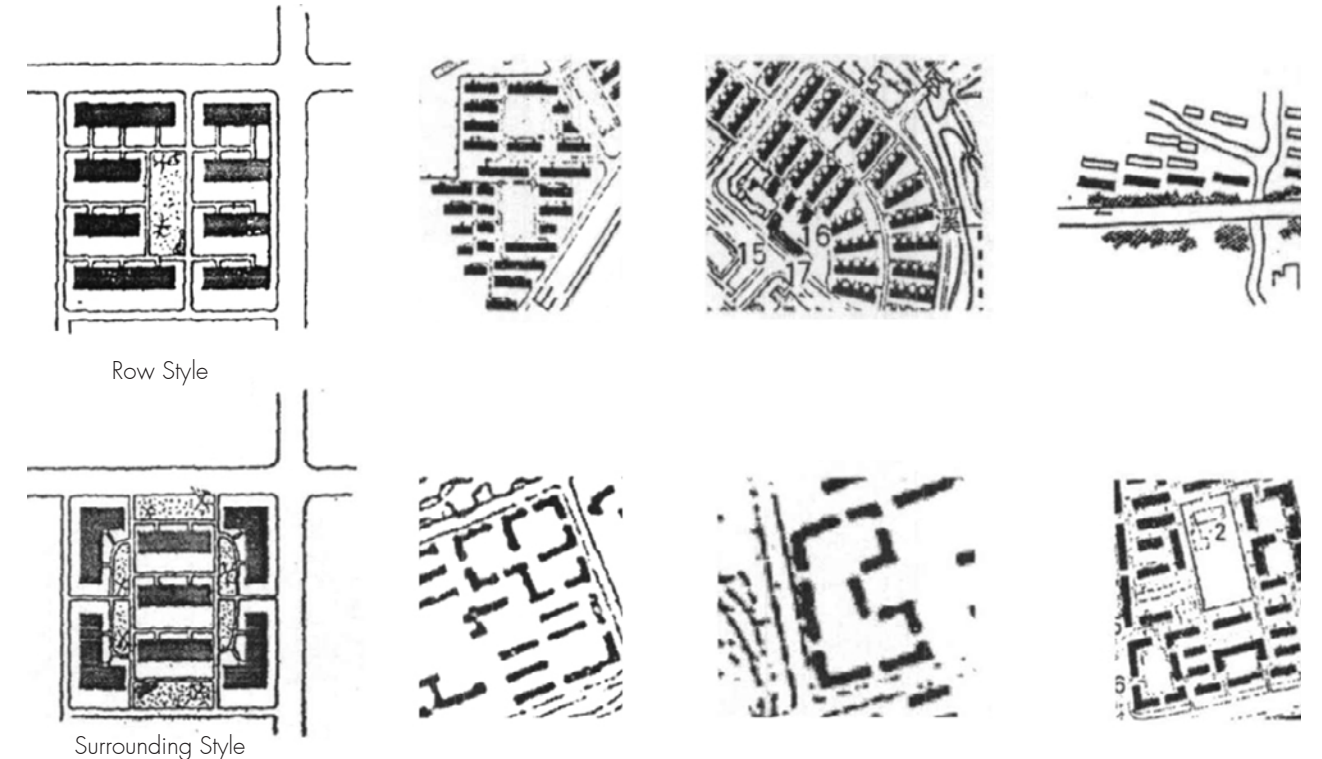


Fig. 4.6| Typology of new workers' estate

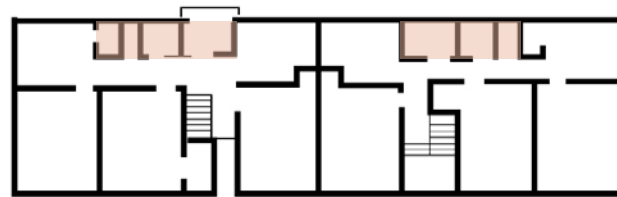
room temperature to rise. The area of the new workers' estate is too small, and a family can only own one room. So the east-facing flats are not popular. Since most new houses do not have heating facilities, the layout form plays an essential role in the life of residents. Under the condition of insufficient housing investment, it is the simplest and effective method to use the natural conditions to improve the quality of the living environment. The north-south-oriented houses arranged in parallel have the advantages of convenient construction, land saving, and low pipeline cost, but the monotonous space of the residential area is its biggest disadvantage.

The 'surrounding' style has also produced a transformation with Chinese characteristics. The buildings on the outside are arranged along the street as surrounding type, and in the middle of the residential area, buildings are still arranged in a row type. In this way, a better urban aesthetic can be obtained, land use is more economical, and public buildings

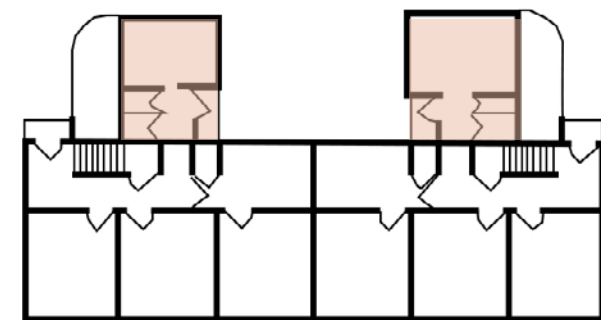
and green spaces can be easily arranged.

Fig.4.6 shows the typology of basic row style, surrounding style, and the actual layout evolved from them. In the early years of the development of row style, there were no significant courtyards. Gradually, concentrated green spaces or other public places began to appear in the community layout. If the long side of the house is along the river or road, it can be arranged along the direction of them. It is not necessary to force the parallelism. The layout of the residential estate is freer, according to the designer's intention.

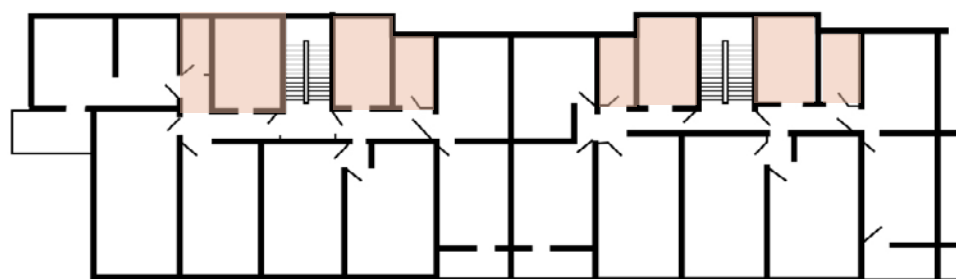
The surrounding style estate is dominated by Caoyang Estate, the earliest of the new workers' estates. By this style, the flexible space design methods can form diverse spaces.



(a)



(b)



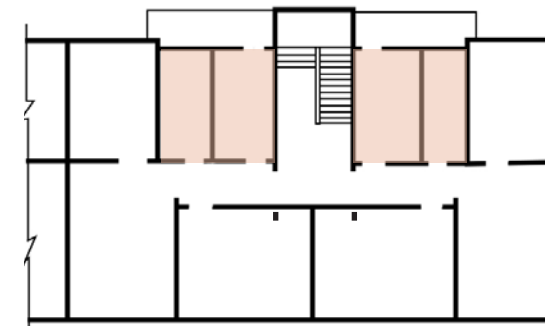
(c)

4.1.3 Typical Typologies of Interior Layout

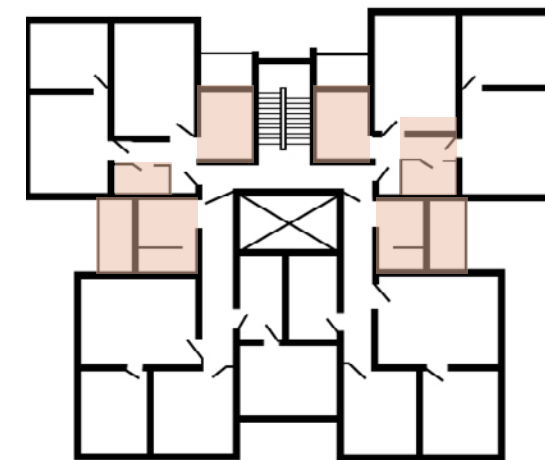
The interior layout of the new workers' estate usually has similar characteristics. Shanghai's professional architectural design agency had launched a series of standard housing types. These types of housing belong to the mode of collective housing, highlighting the economical cost performance and practicality. The interior areas are always smalls in general, but the unit area keeps increasing with the development. The interior design of housing is restricted by the development level of the social and economy, which is the embodiment of the living quality in different periods. These layouts can be divided into the following modes.

Northside corridor type: This is the earliest type of interior layout, with several residents sharing toilets, bathrooms, and kitchens. The bedroom is located on the south side to get enough sunlight, and the toilet and kitchen are located on the north side, connecting to the private living space through the corridor on the north side. Depending on the shape of the building, the layout is slightly different, as shown in Fig.4.7 (a) (b). At the beginning years of this kind of building, the area of each household generally did not exceed 30m².

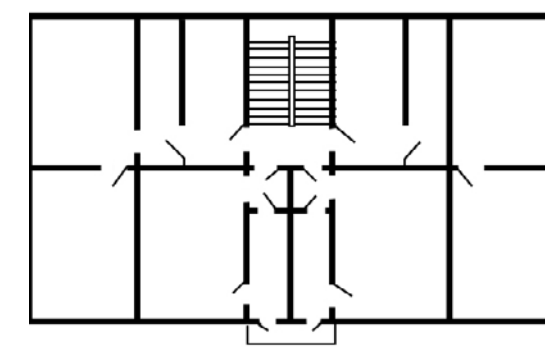
Fig. 4.7| Interior layout of new workers' estate with corridor



(a)



(b)



(c)

Fig. 4.8| Interior layout of new workers' estate apartment

Inner corridor type: There is an east-west corridor in the middle of the flat. The building is divided into two parts, north-oriented and south-oriented. Its characteristics are that in addition to the kitchen and toilets are arranged on the north side of the corridor, and there are larger units on the two sides. There are multiple rooms in one house, and some of them also face the north side, as shown in the Fig.4.7(c).

Apartment-style: The difference between the apartment-style workers' estate and the corridor style is that the whole apartment with shared toilets, bathrooms, and the kitchen has an entrance. Unlike the previous situation, that the toilets, bathrooms, and kitchen are all open to everyone. It is equivalent to sharing an apartment with several residents, as shown in Fig.4.8(a).

Dot-type high-rise: The elevator has been added to the interior layout, and the number of building floors had increased, as shown in Fig.4.8 (b). The overall layout is similar to the apartment-style. It has a significant effect on saving land and giving full play to the investment.

Small-area studio: With the development of the economy, small-sized but rooms with private toilets, bathrooms, and kitchen have gradually appeared, as shown in Fig.4.8 (c). Due to the high economic requirements for space, this has prompted the architects to conduct more in-depth and detailed research on all aspects of inner space, and even comprehensively consider issues such as furniture, building modules, and user habits. Many problems might have been overlooked in the relatively loose living area of the original house, and the architect had to face and think of them at this time (Ding Guijie, 2007).



Fig. 4.9| Site visit of new workers' estates

4.2 THREE TYPES OF NEW WORKERS' ESTATES

The pictures in Fig.4.9 are photos of different new workers' estates. It can be seen from these photos that there is a big difference between the building quality, public space quality, and living quality of new workers' estates built in different eras.

Since the purpose of this research is to apply circular construction to the regeneration of new workers' estates, it is necessary to understand the different regeneration needs and the material flows of different new workers' estates. According to the complexity of regeneration interventions, the new workers' estates are divided into three categories: demolition, refurbishment, and maintain. These three types of regeneration methods correspond to the new workers' estates with different levels of deterioration.

In general, the public spaces in new workers' estates is poor, both in terms of quality and design. However, the building quality of new workers' estates differs significantly, and the deciding indicator in determining which regeneration method to apply to the new workers' estates is the building quality. When the building quality is inferior, and other factors are also appropriate, the method of demolition can be applied. Even if other conditions are suitable, such as the surrounding environment, social, economic, and political conditions, but the building quality is still acceptable, only micro regeneration is applied to reduce unnecessary construction requirements and material flow.



Fig. 4.10| Different quality of new workers' estates

	Building Quality		
	High	Medium	Low
Low Public Space Quality	Maintain	Refurbish	Demolition

Table. 4.1| Three types of new workers' estates

As shown in Fig. 4.10, it is a set of photos of three new workers' estates with different building qualities. The left one is the kind of estates where there are dangers in the structure of the building; the appearance of the building is inferior, the internal environment cannot meet the living demand of the residents, so there is an urgent need to demolish and rebuild. The middle building using time is not very long, and there is no problem with the structural quality of the building, but the appearance and internal layout need to be improved. Only the problematic parts need to be refurbished and updated. The building on the right has a short usage time or has recently undergone regeneration. No additional building updates are required. Only the buildings, public spaces, and equipment need to be maintained on schedule.

In conclusion, the quality of the new workers' estates includes two parts: building quality and public space quality (Ho, D. C. W., 2012). The overall quality of public space is poor, but there are significant differences in building quality. Therefore, the new workers' estates are divided into three types, according to the building quality, as shown in Table. 4.1.

In the following 3 sections, three cases corresponding to the three types will be chosen to make an overview of the current situation.

4.3 SAMPLE 1- MAINTAIN : CAOYANG ESATATE

The sample is one of the new workers' estates, which has the longest history of high-rise new workers' estates and has already experienced several maintenance and regeneration.

It has been almost 45 years since the construction of the old public housing started, and there are some problems with the physical decay. The quality of public space is low, and there is a lot of room for renovation. In the development history of the new workers' estate, it has undergone some regeneration experiences, so the current situation of buildings is good. And there are demands for the improvement of public space and much requirement for maintenance. Therefore, the Caoyang estate is chosen as the sample of Maintain.

Caoyang Estate was built in 1975 and completed in 1977. It consists of 9 high-rise residential buildings with a reinforced concrete structure. Among them, there are three buildings, #1, #11, #21 on Yude Road, and 6 buildings, #750-#1000 on North Caoxi Road. On each floor, there are 4 sets of three-bedroom households with a housing area of about 70 m² and 5 sets of 80 m² house. There are two elevators in each building. These high-rise buildings along the street are landmarks of Shanghai from 1977 to 1990, as shown in Fig.4.15. Caoyang Estate often appears in the TV and film documentaries that reflect the development of Shanghai's urban construction as a typical attraction.

The sample site is located at the edge of the inner ring road, which is the main

	Building Quality		
	High	Medium	Low
Low Public Space Quality	Maintain	Refurbish	Demolition

Table. 4.2| Maintain type of new workers' estates

Site area: 22657m²
Total building area: 76000m²
The number of Hukou households: 1467

center of Shanghai now. (Fig.4.12). The whole site area is 22657 m² and has a total building area of 76000 m². The three buildings in the north have 17 floors, and the six buildings on the south part have 14 stories. The Hukou population is 2960, 1958 people live here permanently, 596 of them come from other cities.

The surrounding environment is good, and public goods are abundant, as shown in Fig. 4.13. There is a metro station just aside from the estate, with three metro lines (line1, 3, 4) going through. In two minutes walk, the residents can reach a bus transfer station, where they can take ten bus lines. On the other side of the road is the Shanghai Stadium sports and culture center. There is one big commercial center in 5 minutes walk and another one in 15 minutes walk. There are rich kinds of retail and restaurants in 10 minutes walk. It is convenient to shop if living in this estate. From the education and cultural perspective, there are two primary schools, one middle school and a museum nearby. Another decisive surrounding factor is that it locates near the government of the Xuhui District, which means that it can ensure the safety of the residential area and provide nice community management. From the perspective of potential waste flow transformation, there is one building material and furniture market nearby. On the south side of the site, there is a storage area, which is rare in Shanghai. But it's also an opportunity in circular design as collection points.

The photos of the current situation of the buildings and public space are shown in Fig.4.14 and 4.15.



Fig. 4.11 | Caoyang Easte



Fig. 4.12 | Location of Caoyang Estate

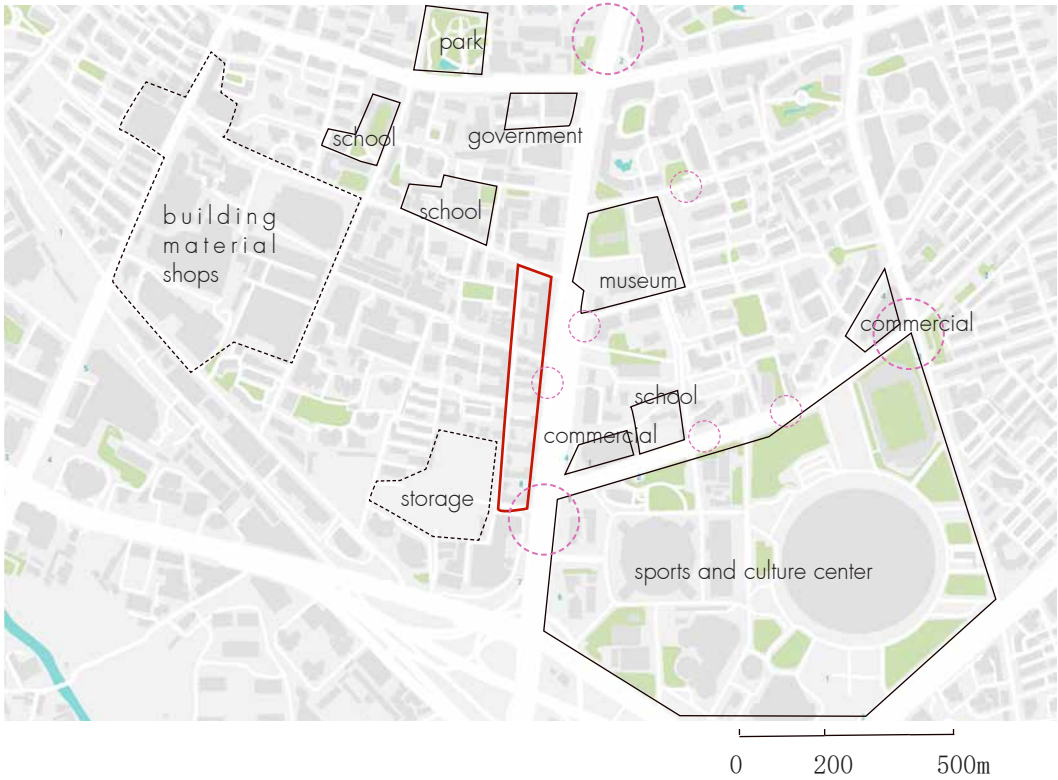


Fig. 4.13 | Surrounding environment of Caoyang Public Housing

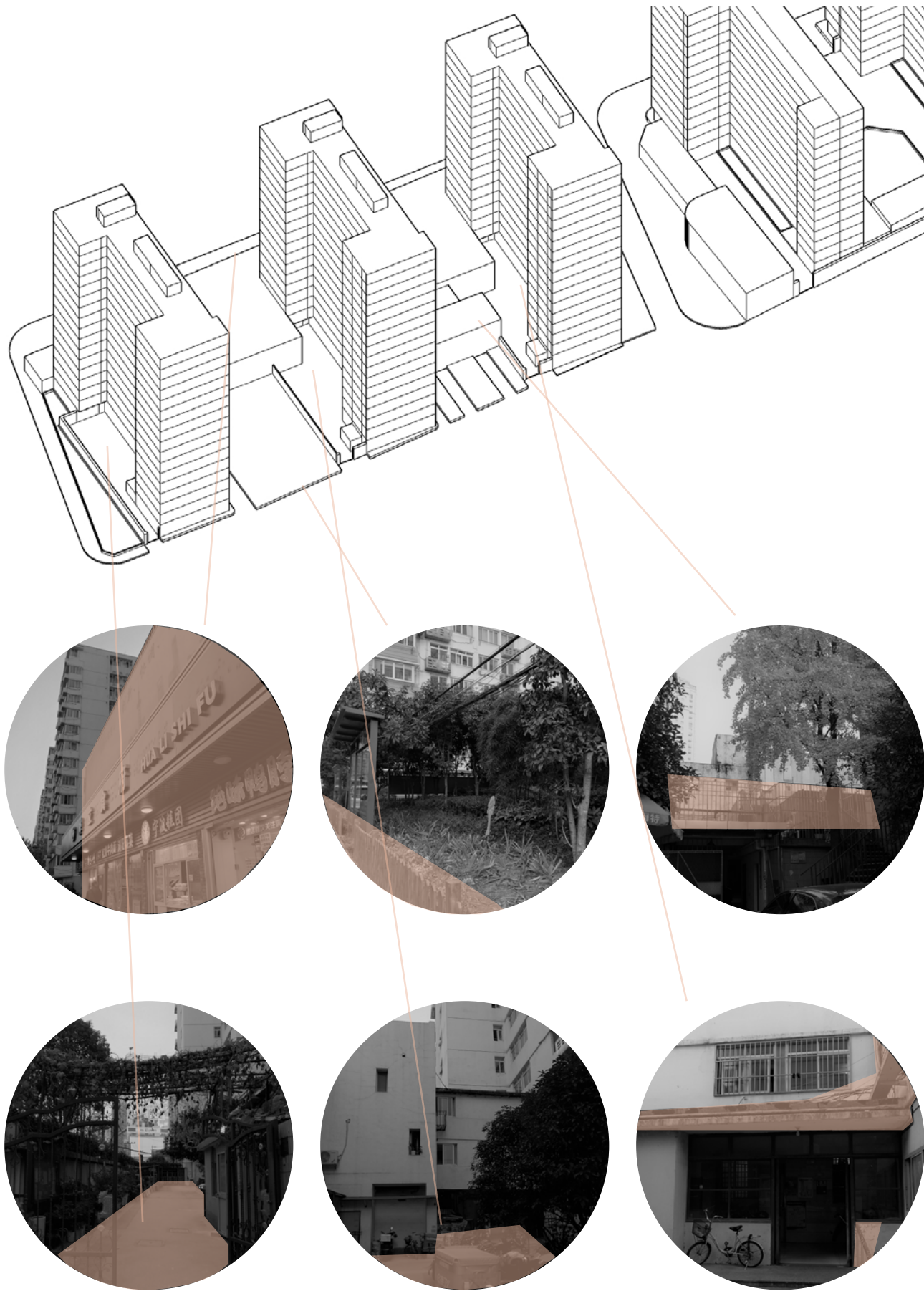


Fig. 4.14 | 3D model of north part and photos

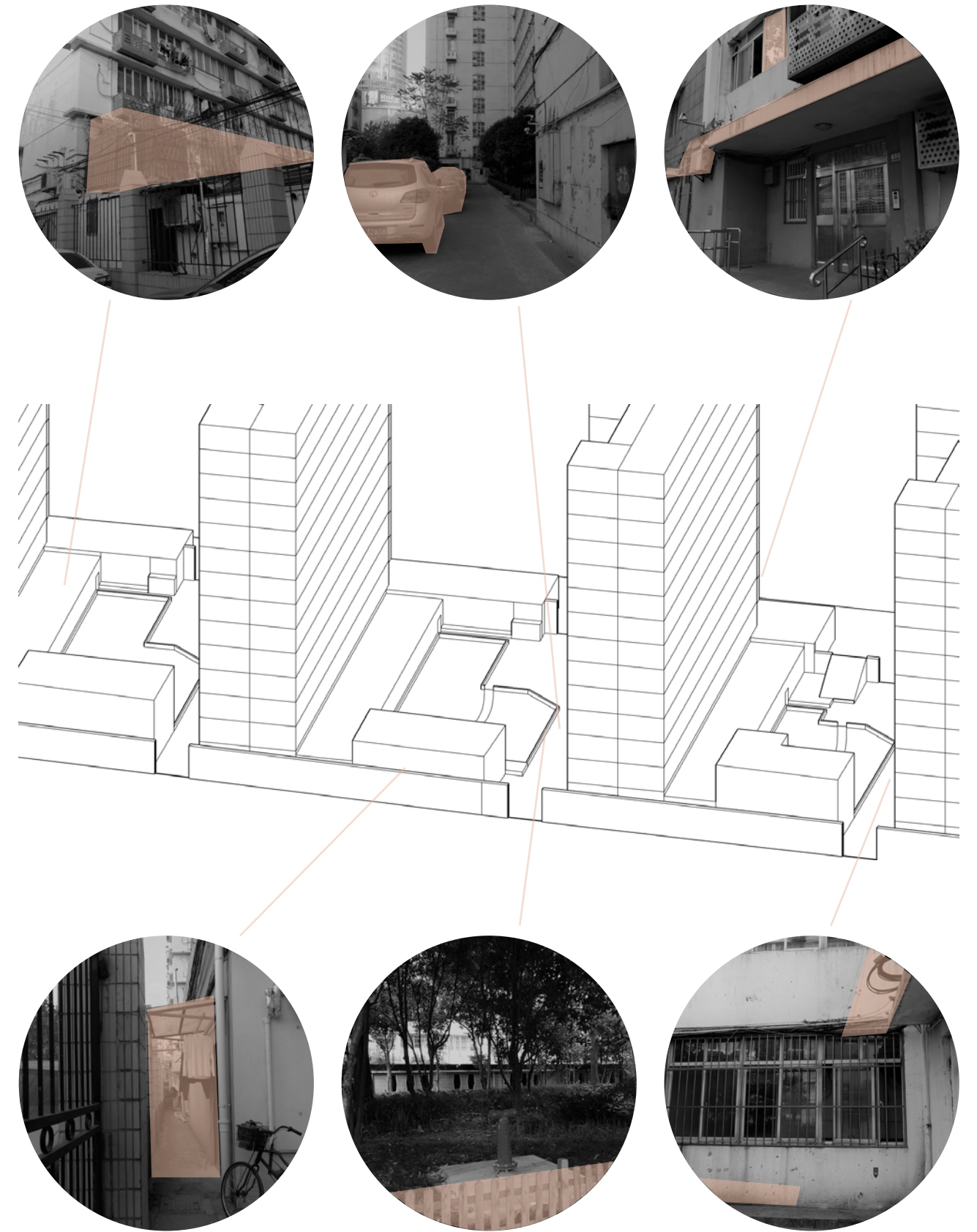


Fig. 4.15 | 3D model of south part and photos

4.4 SAMPLE 2- REFURBISHMENT : NANLING ESATATE

The case of the refurbishment type was selected as Nanling estate, which was built in the 1950s and 1960s and is part of Shanghai 's largest new workers' estate. Some of its buildings have undergone refurbishment regeneration in recent years, and the rest of the build- ings, with medium quality, is a good example of the new workers' estate in the refurbishment category.

There are a total of 22 buildings in Nanling estate, of which 2 buildings have independent kitchen and bathroom space, and the remaining 20 buildings are old public housing. The building structure is a brick-concrete structure. Except for the two six-story buildings, the other residential buildings are all five floors. From the current photo, see in Fig.4.16, the overall quality of the unregenerated buildings is still accept- able, but the facade and interior deco- ration are damaged. At the same time, the most urgent need for regeneration is also to transform public housing into independent apartments. Because the quality of the building is acceptable, it is not necessary to completely demolish the building, but it can be regenerated by means of refurbishment.

The sample site is located at the edge of the inner ring road, which is the main center of Shanghai now. (Fig.4.17). The whole site area is 37892 m² and has a total building area of 45000 m². There are 1467 households currently living here.

The sample site is surrounded by the inner ring road and central ring road,

Low Public Space Quality	Building Quality		
	High	Medium	Low
	Maintain	Refurbish	Demolition

Table. 4.3| Refurbishment type of new workers' estates

Site area: 37892m²
Total building area: 45000m²
The number of Hukou households: 1467

which is the center of Shanghai. It also locates near the future development axis of Putuo District and the core of the whole Caoyang Community. There is also a poten- tial for it to have a link with the urban waterfront green corridor. All in all, the location of the site is excellent, public goods, landscape resources, and future development potential are also magnificent, with extremely high renewal value, as shown in Fig.4.18.

The photos of the current situation of the buildings and public space are shown in Fig.4.19. For buildings in the estates, especially the ones that haven't been refurb- ished, there are problems with broken facades, chaotic wires, and various stuff hanging outside the windows, which are in stark contrast with the facades of the buildings that have been regenerated and are very unsightly. The interior of the building is also dilapidated, for example, the surface of the wall is peeled off, and the stairs are damaged. All these things influence the living quality. But the building structure is still in good condition. Most importantly, the interior layout of public hous- ing needs to be regenerated into separated apartments.

For the public space of the sample estate, there is little open space or green space except for the roads. And the existing green areas are not designed and used prop- erly. The row style of building layout makes the public space homogeneous and lack of interest. In conclusion, there is great potential in the improvement of public space quality.



Fig. 4.16 | Nanling Easte



Fig. 4.17 | Location of Nanling Estate



Fig. 4.18 | Surrounding environment of Nanling Estate

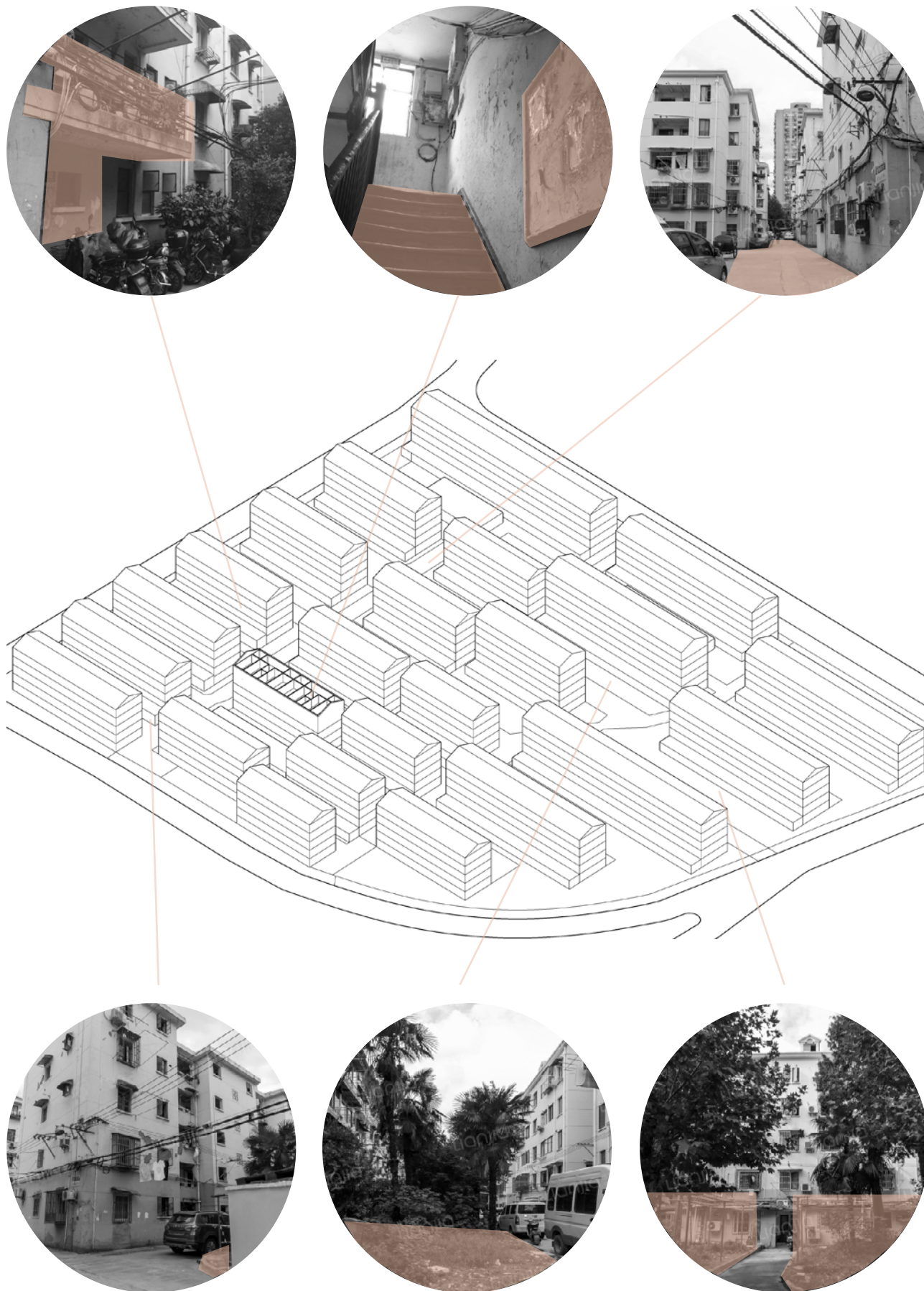


Fig. 4.19 | 3D model and photos of Nanling Estate

4.5 SAMPLE 3- DEMOLITION : PENGPU ESTATE

For the new workers' estate of the demolition type, select a site that has completed the demolition as a case study to demonstrate the characteristics of this type of new workers' estate and the feasibility of this regeneration method.

Pengpu Estate is located in Zhabei District, Shanghai, as shown in Fig. 4.20. It has a total area of 3,000m², a total building area of 1500m², and a total of 427 houses.

Pengpu Estate was built in 1958 and was one of the first new workers' estates in Shanghai. Since 2008, Pengpu Estate has been demolished and rebuilt. Demolition of the original old public houses, and then build new apartments to solve the problem of independent use of kitchen and bathroom. The reason why the Pengpu Estate became a pilot for demolition is that in addition to sharing kitchens and bathrooms, there are serious problems such as aging of the housing structure, severe flooding issues, and clogging of the water supply and drainage pipes. The situation before regeneration is shown in Fig. 4.21. It is no longer possible to improve the quality of living through simple regeneration methods.

After the 15 old buildings were demolished, 3 18-story high-rise residential buildings and 3 8-story high-rise residential buildings were built on the original site. As the first demolition project of high-rise regeneration estates completed in Shanghai, all 6 residential buildings were equipped with elevators (Gu Wenyan, 2013). The new estate after

	Building Quality		
	High	Medium	Low
Low Public Space Quality	Maintain	Refurbish	Demolition

Table. 4.3| Demolition type of new workers' estates

Site area: 1500m²
Total building area: 450m²
The number of Hukou households: 427

regeneration is shown in Fig. 4.22.

During the design, the designer took into account the principles of fairness and humanity and designed 34 types of units for residents to choose from. Although the principle is "reconstruct as much as the area is demolished," the actual floor area of each household is more than the original. The ground space that was vacated after the construction of the high-rise building was used as public spaces to improve the living quality. For example, an underground parking garage that can accommodate 285 vehicles, a large amount of green area, and community public buildings with a construction area of more than 6000 square meters space are built(Gu Wenyan, 2013).

The demolition regeneration is based on residents' aspirations and government support. The policy has been beneficial. In addition to the subsidies and rewards of 3,000 yuan for signing incentive fees, 1300 yuan for equipment migration fees, and 1,000 yuan for moving costs, each household gets a monthly fee of 2,200 to 3,200 yuan according to the size of the house. The fee is equivalent to a part of the rent and decoration costs of the residents to live in a new house (Xiang Xuan, 2011). According to the public housing purchase policy, residents can buy houses at relatively low prices. In this way, the property rights of the house are changed from a public house to a house with private property rights, which can be traded again in the future.

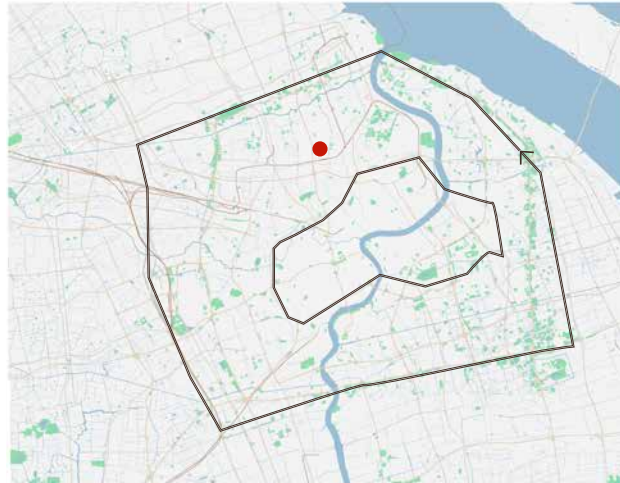


Fig. 4.20 | Location of Pengpu Estate



Fig. 4.21 | Pengpu Estate before regeneration



Fig. 4.22 | Pengpu Estate after regeneration

4.6 CONCLUSION

- Location of new workers' estates

The location of the new workers' estates are always at the edge of the city at the time of construction, but the first built communities have the longest use time. They are already located in the center of the current city, which means that they have a high value for regeneration.

- Typology of new workers' estates

- Typical typology of the new workers' estate is the row style, the maximal arrangement of housing determines the lack and monotony of public spaces
- The typical typology of the interior layout is the sharing functions. Therefore, the most severe problem of the new workers' estates is that most of the housing shares bathroom and kitchen, which can't meet the current demand of residents.

- Classification

- The regeneration methods can be divided into three categories: Demolition, Refurbishment, and Maintain, depending on the quality of the status quo.
- High building quality and low public space quality corresponds to maintain regeneration. This could involve micro-regeneration and daily maintenance. Take Caoyang Estate as an example.
- Medium building quality and low public space quality corresponds to refurbishment regeneration. This could involve the renewal or demolition of buildings partially and regeneration of public space. Take Nanling Estate as an example.
- Low building and public space quality correspond to demolition regeneration. This means to totally demolish the original new workers' estates and make new planning and designs. Take Pengpu Estate as an example.

5

PROCESS AND EVALUATION

Current status of public space and regeneration

5.1 CURRENT REGENERATION MODE

Since the construction of the new workers' estates, with more and more problems occurs, they have undergone some regeneration. For example, 'flat to slope' and 'comprehensive regeneration.' In the following, these transformation measures will be classified, and the interventions of regeneration will be introduced. At the same time, through the case, investigate and calculate the material flow involved in the traditional regeneration methods. Finally, the social and economic problems of the current transformation model are analyzed.

5.1.1 Historical Regeneration Interventions

Structure and Interior layout

1. Add extra floors

To creating more areas for increasing living demands, some additional stories were added on the top of buildings, under the premise of ensuring structural safety, see in Fig. 5.1.(1).

2. Demolition

It is a plan in which residents first move away from old houses, and then the old houses are demolished and rebuilt by the government on the site, and the residents will move back after the new buildings are built, as shown in (2). After the regeneration, the living area is slightly expanded, and residents can also have an independent kitchen, sanitation facilities, and a more reasonable interior layout, which fundamentally improve the living quality. But the problem is the high cost.

3. Broaden refurbishment

This method is mainly aimed at the old public housing with a large distance between the front and back of buildings. There is a possibility of widening the throat of buildings, as shown in (3). After the regeneration, the interior layout became more reasonable, and the usable area expanded accordingly. However, due to planning and other restrictions, the "subsidy" area is limited, and the increase in the area of each household is also likely to be uneven.

4. Internal re-partition

This is one of the main ways of the existing old residential estate comprehensive regeneration in Shanghai by redefining internal divisions. It is to renovate the original shared kitchen and bathroom space and allocate it to each household. As shown in Fig.5.2, a public apartment is divided into two separate and independent apartments through re-partition. This method is also difficult to adopt in some public spaces with particularly narrow spaces.

5. Partially remove

It is to extract 1-2 households on each floor and relocate to other residential areas to allocate the vacated space to other residents. However, this involves housing issues, and the operation is also complicated.

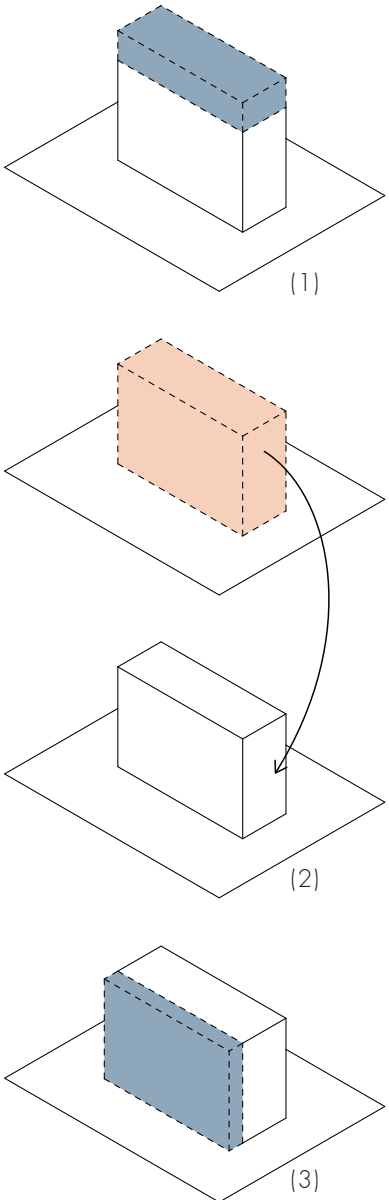


Fig. 5.1 | Structural regeneration

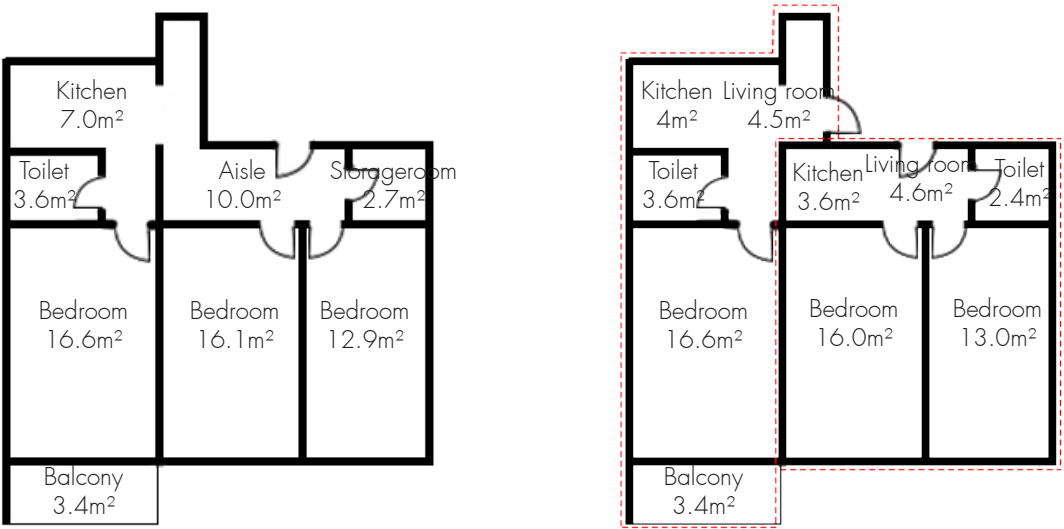


Fig. 5.2 | Interior layout regeneration



Fig. 5.3 | Vertical facade regeneration

Facade

1. Vertical facade

Take the vertical facade regeneration of Caoyang estate as an example. In the beginning, the facade of the Caoyang estate was partially gray, and with the cement as the surface of the wall. During the first regeneration, the gray-colored exterior walls were turned into yellow glazed tiles, as shown in Fig. 5.3. In 2007, the World Special Olympics was held in Shanghai Stadium. The Caoyang estate is just located across the street to the Special Olympics. At the same time, it was the time to welcome the World Expo, so the city's appearance and environment experienced large-scale regeneration. To improve the environment and the appearance of the city, and at the same time solve the problems of poor thermal performance of the facade structure, water seepage, cluttered appendages, and hidden safety hazards that have existed in the Caoyang estate for many years, the regeneration project has been implemented. It was funded by the Xuhui District Government and organized by the Xuhui District Real Estate Bureau. (Zhao Weiming, et al., 2008)

Before the regeneration, no thermal insulation measures were taken on the external walls, and the windows are single-layer glass with steel frame. The original vertical decoration of the building facade is partially missing, and some of the wall surfaces have water seepage to varying degrees. Some of the wall bricks were loose, and there is a danger of falling off at any time. It can be seen from the infrared thermal image that there is an apparent phenomenon of empty drums. There are many appendages on the external wall, such as goal-type drying racks, outdoor air-conditioning racks, awnings, and other external wall accessories with different patterns. Some of them have rusted, and there are hidden safety risks. The exterior wall

Sources: lunwen
https://www.sohu.com/a/281868838_120058888
<http://news.iqilu.com/shandong/shandonggedi/20160615/2847266.shtml>

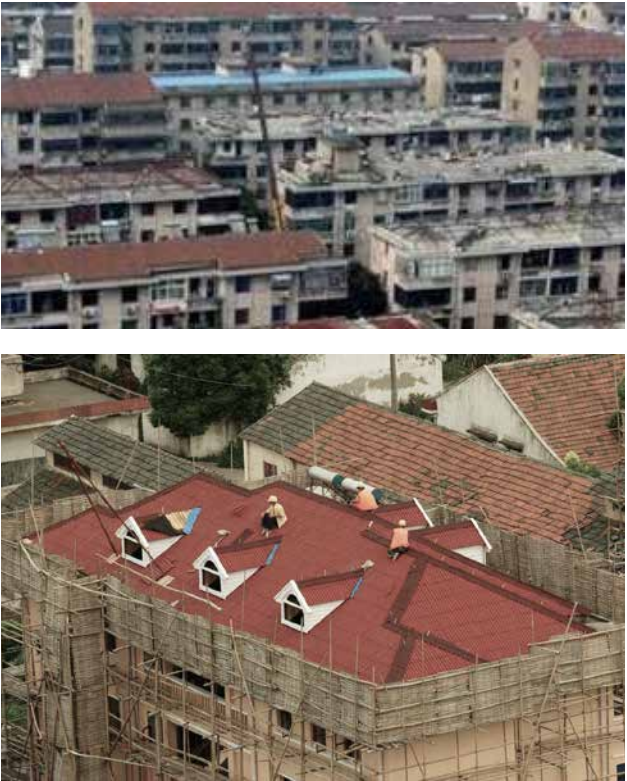


Fig. 5.4 | Roof regeneration

was initially a beige-colored brick exterior. The energy-saving reconstruction uses a 35mm extruded polystyrene (EPS) outer wall exterior insulation system and exterior paint. The outdoor racks of the air conditioner are uniformly set, and the hot-dip galvanized angle iron is used as a frame, and the cover is a stainless steel punching plate. The goal-type drying rack was changed to a telescopic stainless steel drying rack. The exterior walls are covered with thermal insulation, and the windows are replaced with aluminum alloy frame. The balcony panel on the east facade of the building adopts wall greening facilities, and small bushes are planted to form a three-dimensional green wall. The main body of the exterior wall paint is milky white, and the wall on the east side is light brick red, which is in harmony with the surrounding environment. Lighting belt was set around the roof of 9 high-rise buildings to increase night lighting for landscape (Shao Zheng, Yan Hongliang, 2018).

2. Flat roof to sloping roof

Since 1999, the regeneration of 'flat to slope' in the old residential area of Shanghai was mainly carried out for the existing multi-story houses. "Flat to slope" converts flat roofs of multi-story houses into sloping roofs under the condition of building structure permission, to improve the quality of dwellings and visual effects of building appearance, as shown in Fig.5.4. The new workers' estates were mostly flat-topped when they were built. However, the roof of a flat-roof building is prone to leakage and poor insulation. There are many advantages to changing to a sloping roof, such as making a beautiful shape; having no water accumulation and excellent waterproof performance; to use slope roof space to increase the area without generating great shadows, and saving energy.

Facility and infrastructure regeneration

The service life of the facilities and infrastructure in the estates are not as long as the buildings, so they need to be regularly maintained and updated. Take Caoyang estate as an example. The smoke exhaust pipes and circuit systems in the building need to undergo renovation. During 2018-2019, the community transformed fire protection facilities and secondary water supply. Fire protection facilities regeneration mainly includes adding or repairing damaged fire protection equipment (such as fire emergency lighting, evacuation instructions, fire extinguishers, alarms), electrical circuit reconstruction, adding facilities of centralized charging devices for electric bicycles,

and encouraging the communities to use the Internet to improve the response efficiency; install simple sprays in households, homestays, and rented dwellings through raising funds by residents and government subsidies.

Secondary water supply facilities supply water to middle and high-rise residents through internal re-pressure. It is a facility regeneration project to reduce the intermediate process and improve the technical content of the water supply system. Water quality and water pressure will be significantly improved, and energy efficiency and automation will be enhanced.

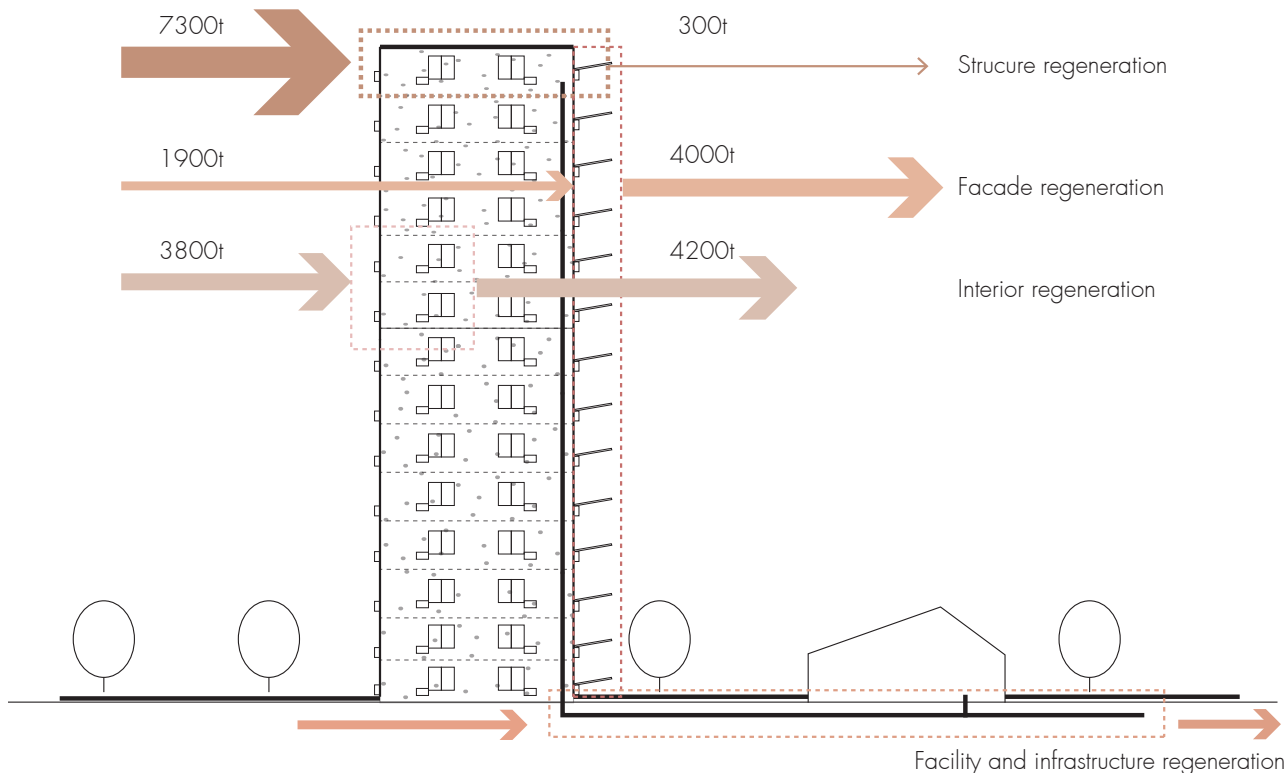


Fig. 5.5 | Material flow of current regeneration

5.1.2 Regeneration Material and Waste

Also, take the Caoyang Estate as an example. The building in the case is reinforced concrete structure, and the building materials of it mainly include concrete, metal, brick, plastic, glass, and other materials. The discarded and required materials for different types of regeneration are also different.

When it was added one more floor in 1994, the six buildings on the south side each had an additional area of 560 m², and the three buildings on the north side each had an additional area of 500 m². The waste generated is mainly construction waste and decoration waste, of which construction waste (excluding construction mud) is about 250t, and decoration waste is about 50t. The construction waste includes 50t of concrete, 50t of bricks, 12t of packaging materials, and 20t of steel. The construction materials consumed during the new construction process are about 7,300t, including 1200t of cement, 250t of steel, 480t of brick, 2000t of sand, and 2500t of stone. 300t of waste is generated, and 7,300t of material is consumed.

materials consumed were insulation materials, paint, metal supports, and windows. Demolition of the original bricks from the exterior wall during the reconstruction process resulted in approximately 1800t of demolition waste. All kinds of metal attachments on the external wall are about 18t, and about 9800 old steel windows are removed and replaced with new plastic steel windows. The standard metal attachments on the outer wall are 30t, and the wall is re-insulated and painted. It produces about 4000t of waste and consumes 1900t of materials, as shown in Fig.5.5.

Most of the materials involved in equipment renewal are pipes, equipment, and materials that are difficult to count. But it is still a regeneration that replaces old materials with new ones.

The internal regeneration avoided moving the interior wall as much as possible, and only the decoration was renovated. The demolition of the original internal decoration waste involved was about 3400t, and the decoration waste was about 760t. This process consumes 3800t of decoration materials, data according to the interview of the property company and the management office.

When the facade was regenerated in 2007, the main ma-

5.1.3 Social & Economy perspectives

Property right

At present, there are several types of property rights of houses in China: market housing, affordable housing, military housing, public housing, the house with limited property rights, and self-built housing. Market housing refers to a house developed and operated by a real estate developer. From a legal perspective, it can be freely traded on the market following laws and related regulations and is not subject to government policies. Public housing refers to housing invested, constructed, and sold by the government and state-owned enterprises and institutions. Before the house is sold, the property rights (ownership, possession, disposition, income rights) of the house belong to the state or the property rights enterprise.

The community in the case was a public house when it was built. After the reform of property rights, renting residents paid some fees, and after purchasing the dwelling they lived in, they could change the property rights of public housing to market housing. According to the survey, most of the property rights in the estate have been converted into market houses (Huang Sha, 2016).

Social differentiation

In the survey, the author found that the residents were clearly divided into two categories. One is the residents who lived here from the beginning of the construction. They have been neighbors for decades and may also be colleagues in their work. They are very familiar with each other. Some people are gradually selling or renting houses to others. Most of these houses are bought or rented by young people with low incomes, who are unfamiliar with each other and have significant differences in living habits from the original residents. There is, therefore, little communication between the two groups.

Public participation of regeneration

In recent years, the government has promoted public participation. The government stipulates that it is necessary to publicize the meaning of the regeneration of old estates through various media. The comprehensive regeneration plan of each community must be publicly displayed to the residents in an intuitive way. In the process of publicity, they must fully listen to the residents' feedback, and strive to achieve support for the regeneration program and maintain the results of the regeneration together. According to regulations, the residents' participation methods include participation in decision-making on the content of the regeneration and participation in the implementation of the regeneration.

The residents' spontaneity mainly generated public participation in the regeneration work of the old estates. Other social organizations and non-governmental organizations did not participate a lot. The spontaneous participation of residents can only be supervision. The scope of involvement is not broad enough. The fact is that most residents think that the regeneration and reconstruction of old estates should be the responsibility of the government at all. Therefore, the enthusiasm of the residents cannot be mobilized. At the same time, residents also lack the methods to participate in decision-making.

Fund of regeneration

According to relevant government regulations, the source of funds for the regeneration of the old estates can be divided into two parts: government investment and social investment, government investment mainly refers to financial investment, maintenance funds for housing, and house sales after regeneration. Social investment refers mostly to relative enterprise funds, public accumulation funds, and other social investments. The investment method is as follows:

1. The financial department will invest in the key regeneration projects of the old estates and the related infrastructure renovation projects with different proportions. For example, the regeneration of the housing structure and equipment will be carried out by the government and the community, according to a 1: 1 investment. Besides, for the road, greening and other environmental improvement related projects are funded by governments.
2. The funds come from house sales after regeneration, maintenance funds, and public accumulation funds are used for the regeneration of residential equipment or additionally adding new equipment. This mainly includes the renewal of facilities and equipment such as water, electricity, and heat; the transformation of rainwater collection systems; the regeneration of fire protection and security systems; and build extra parking spaces, etc.
3. The professional company invests in the public network, heat, water, gas, electricity, and other pipe networks and equipment renovation of the old estates. The government will give fixed subsidies to professional companies according to the situation.
4. The optimization regeneration of the estate is mainly carried out through social investment. It mainly includes projects such as adding elevators, greening roofs, rebuilding basements, and applying solar technology.

In the regeneration process, there are few personal funds invested. Generally, the economic conditions of residents in old estates are not very good. This kind of regeneration and improvement can't change their financial status, and the new construction area produced by the regeneration and development still needs to afford by themselves. Moreover, residents are more inclined to use this cost to buy new homes. Therefore, the primary source of funds for the regeneration of old residential estates is still the government's financial investment, as well as some of the house sales after regeneration and housing maintenance funds. In the process of regeneration, the proportion of social investment is not enough (Ge Yan, et al, 2017).

5.2 REGENERATION MODE: MAINTAIN&REFURBISHMENT&DEMOLITION

As mentioned in 4.2.6 above, the new workers' estates are divided into three categories according to indicators such as building quality and living quality. Due to the different status quo of these three types of new workers' estates, the regeneration mode required is also different. In this section, the three types of regeneration modes will be described, introducing future regeneration measures and material flow that may occur.

5.2.1 Demolition

The demolition mode is suitable for new workers' estates with deplorable building conditions and poor living quality. The new workers' estates are mostly public housing, to complete the 'comprehensive regeneration,' the interior of the building needs to be re-divided. Due to the extremely poor building conditions, it is difficult to renovate part of the building, and the potential for regeneration is small. Therefore, it

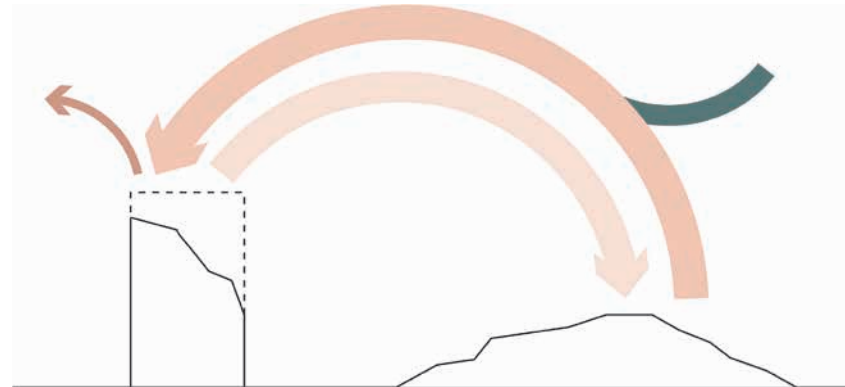


Fig. 5.6 | Material flow of demolition

is more appropriate to choose to demolish and rebuild directly. This can fundamentally improve the quality of life. In this process, the wishes of the residents are essential, and the support of relevant funds must be obtained to make the project feasible.

The material flow of this process is shown in Fig. 5.6. A large amount of demolition waste flows out of the demolished building. After the circular process, the secondary materials, together with bio-based materials, will be used back to the reconstruction of new workers' estate. During the reconstruction, construction waste and decoration waste will be generated.

5.2.2 Refurbishment

Some new workers' estates have not been used for a long time, and the damage to the building is not very serious. It only needs 'comprehensive regeneration' or a partial update. For them, refurbishment is a more appropriate regeneration mode. There are also some new workers' estates, due to the complicated ownership of property rights, it is impossible to complete all the regeneration at once. The remaining unrenewed parts can also adopt this regeneration mode. This refurbishment mode includes updating the structure, facade, interior, and facilities of the building.

The material flow of this process is shown in Fig. 5.7. Some demolition waste flow out of the refurbished site, after the circular process, the secondary materials, together with bio-based materials, will be used back to the reconstruction of new workers' estate. This mode differs from the demolition mode in that the amount of material flow is smaller.

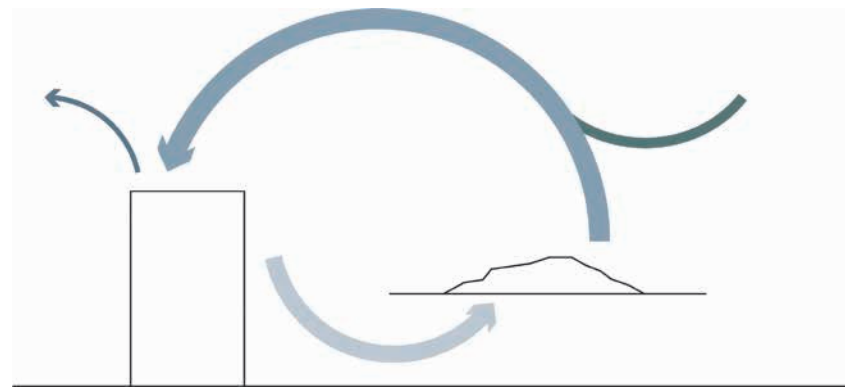


Fig. 5.7 | Material flow of refurbishment

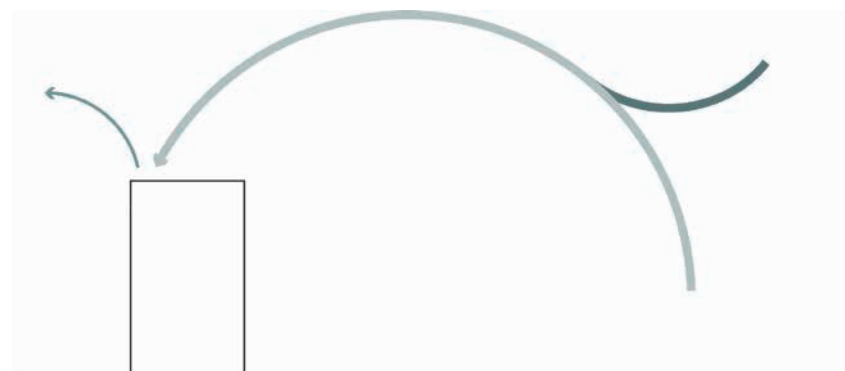


Fig. 5.8 | Material flow of maintain

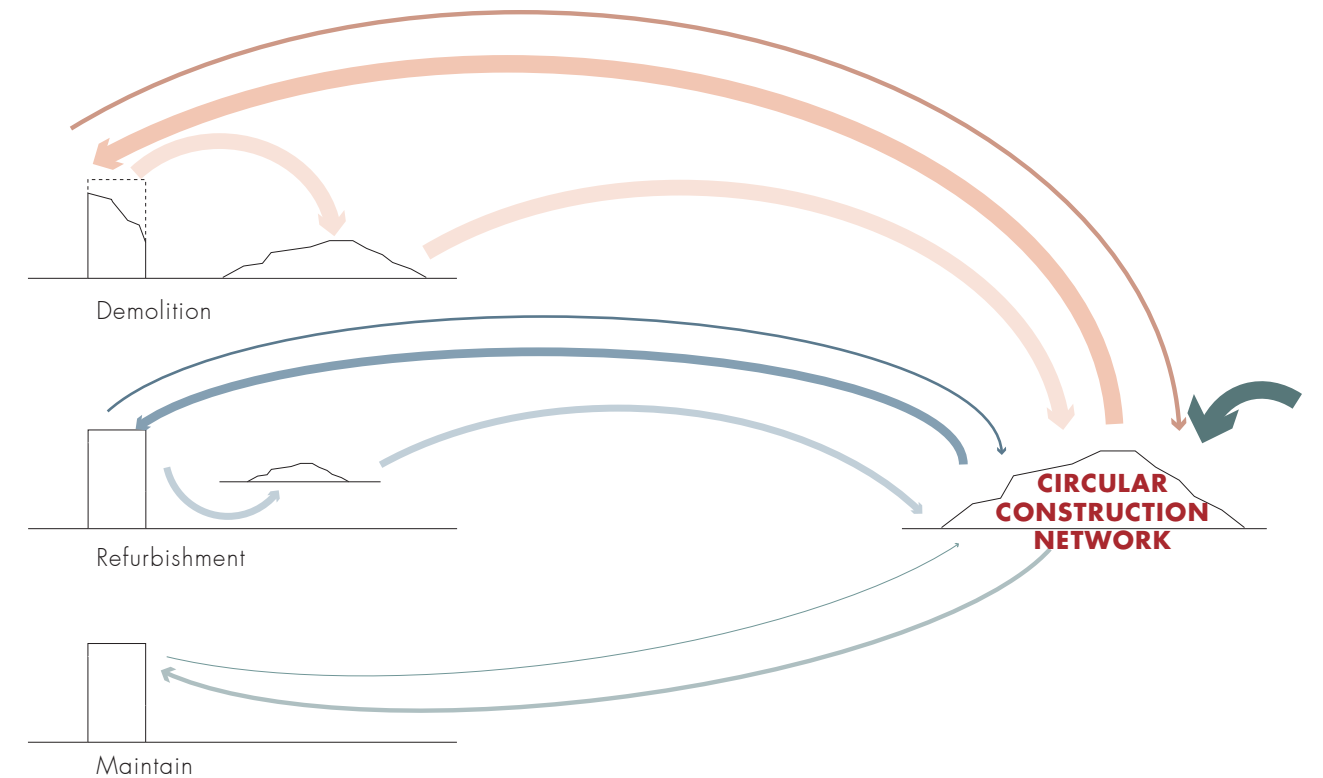


Fig. 5.9 | Overall material flow

5.2.3 Maintain

There are some new workers' estates that have completed building regeneration and those non-public apartments which have been built only in the past 30 years. The buildings themselves do not need to be renewed, but only maintenance is required to extend the service life and improve living quality. These new workers' estates are suitable for using the maintain mode. This regeneration mode includes the maintenance of the building's facade, structure, interior decoration, and facilities. Timely maintenance can significantly reduce the need for future regeneration.

The material flow of this process is shown in Fig. 5.8. There is almost no material flows out of the maintain site, but the secondary materials from the other two modes, together with bio-based materials, will flow to these estates.

5.2.4 Overall material flow

In summary, the combination of three modes of material flow is shown in Figure 5.9. The first two regeneration modes have materials flow out, but the amount is different. After collection and concentrate processing, these wasted materials are reprocessed into secondary materials. These materials, together with bio-based materials, will then be applied to the regeneration of the three types of new workers' estates. The waste material generated during the reconstruction process is again used circularly. This is a complex process that includes multiple categories of materials, various sources, various destinations, and numerous processing methods. Therefore, a platform is needed to enable multiple processes to be coordinated and managed to improve the efficiency of circular construction. This platform is the circular construction network. By categorizing the regeneration modes of different new workers' estates, we can get a preliminary understanding of the source of circular materials and their application objects.

In general, according to the comparison of three regeneration modes, the refurbishment interventions actually include some operations of demolition and maintain, which is the most comprehensive and complex of the three modes. Therefore, in the following research, refurbishment mode will be the main research object.

- Demolition waste
- Secondary material
- Construction&Decoration waste
- Demolition waste
- Secondary material
- Construction&Decoration waste
- Secondary material
- Construction&Decoration waste
- Bio-based materials

5.3 EVALUATION OF REGENERATION

5.3.1 Satisfaction assessment of regeneration

This section evaluates residents’ satisfaction with the current regeneration projects and the effect of the regeneration through a survey of residents from the sample site. A total of 20 questionnaires were distributed. And analyze the satisfaction evaluation of residents.

Questions of the survey are shown in Table 5.1 below. ‘Please make an evaluation of the residential area you are living in. If the following areas have been updated in recent years, please evaluate these improvements.’

	Satisfy	Ordinary	Dissatisfy
Building interior quality			
Road and parking facility			
Public and green space			
Public goods			
Infrastructure			

Table. 5.1 | Evaluation of the residential area before and after regeneration

From the analysis table, Table.5.2, it can be seen that before the renovation, the most satisfied subdivisions of residents are public goods, and the most unsatisfied items are roads and parking facilities. However, the most satisfying items are still public facilities, and the most dissatisfied items are still roads and parking facilities after regeneration, see in Table.5.3.

After the renovation, the number of “satisfy” is obviously increased in the interior of the building. At the same time, the evaluation of green space and public space, roads, and parking facilities are always low. It can be seen that the previous

regeneration focuses on the regeneration of the building itself, and the residents have also recognized this part of work. For green space and activity areas, the regeneration projects involve less. The regeneration of road and parking facilities is difficult and limited by the narrow space.

After the regeneration, the other aspects of the old residential area have been improved; on the contrary, public space regeneration appears to be relatively weak in the new workers’ estates. They still cannot meet the needs of the residents.

	Regeneration project	Number	Proportion
Satisfy	Building interior quality	6	30%
	Road and parking facility	6	30%
	Public and green space	8	40%
	Public goods	16	80%
	Infrastructure	11	55%
Dissatisfy	Building interior quality	12	60%
	Road and parking facility	16	80%
	Public and green space	13	65%
	Public goods	6	30%
	Infrastructure	4	20%

Table. 5.2 | Evaluation of the residential area before regeneration

5.3.2 Regeneration Aspiration and Demand

Investigate the residents of other estates from a larger area, and investigate the residents’ willingness and needs for the regeneration of the old residential estates. A total of 188 questionnaires were retrieved. 49 of the 188 people live in estates aging for more than 30 years. The results are as follows.

For old estates with a building age of more than 30 years, such as new workers’ estates, in general, residents’ demands and aspirations for all types of regeneration are higher. The most noticeable feature is that residents’ desire for public space regeneration is slightly stronger than that of residents who live in 5-30 years buildings, and twice that of residents who live in houses less than 5 years, see in Fig.5.10.

The result of ‘what do people living in estates over 30 years think the public space regeneration of the community needs to be’ is shown in Fig.5.11.

	Regeneration project	Number	Proportion
Satisfy	Building interior renewal	11	55%
	Road and parking facility	5	25%
	Public and green space	9	45%
	Public goods	17	85%
	Infrastructure	14	70%
Dissatisfy	Building interior renewal	4	20%
	Road and parking facility	17	85%
	Public and green space	15	75%
	Public goods	3	15%
	Infrastructure	3	15%

Table. 5.3 | Evaluation of the residential area after regeneration

Based on the content of the above two sections, it can be concluded that according to the residents’ satisfaction with the current regeneration and the demands and aspirations for the future regeneration, the renovation of public space is the most important part of the future transformation.

From a planner’s perspective, public space that cannot meet the demand of living quality will lead to the replacement of original residents by less affluent residents, which will accelerate the decay of the estates, resulting in a larger number of demolition and new construction. Through the regeneration of public space, it can reduce future regeneration demand, meanwhile, solve some social problems. Therefore, it is a potential research object to achieve the sustainable regeneration of the new workers’ estates at the smallest cost.

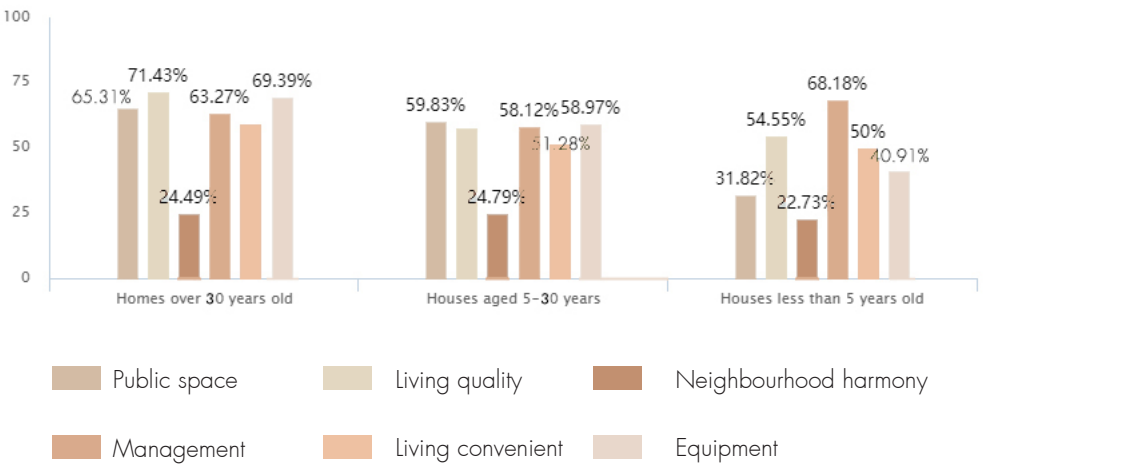


Fig. 5.10 | What do you think the community needs to improve first

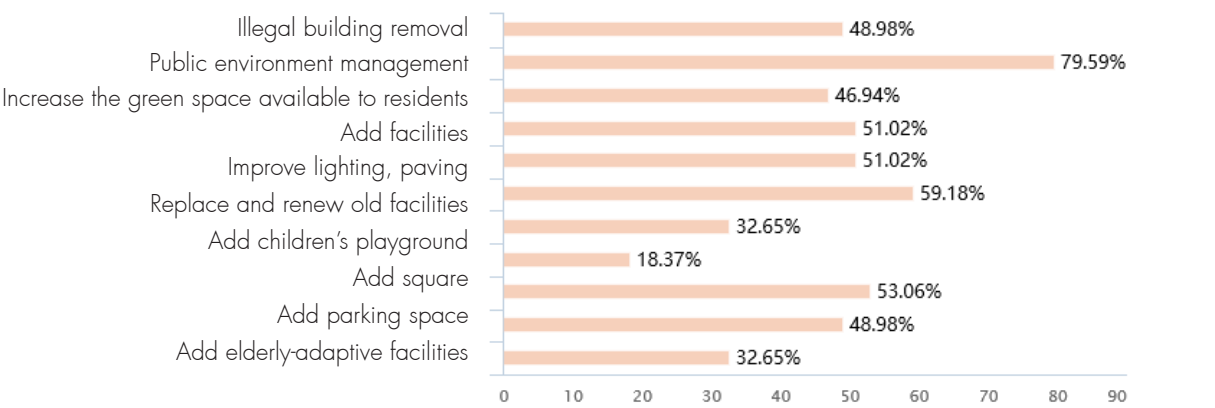


Fig. 5.11 | What do people living in estates over 30 years think the public space regeneration of the community needs to be

5.3.3 Views on circular construction

As the main topic of the research is circular construction, the author also investigates these people on their views on it. We can see from the result in Fig. 5.12 that, currently, people have higher recognition and understanding of using circular decoration materials and furniture. People have the least knowledge of using circular materials on buildings, and some people are entirely reluctant to live in such buildings. During the interview, most of the reasons for refusing to use circular construction on buildings are not understanding and not trusting this new method. Therefore, more promotion is needed.

Applying circular materials to public spaces is in between these two situations. It could be an ideal transition step for the promotion of circular construction. Select pilot projects for experimental popularization, and gradually make users accept this new regeneration method.

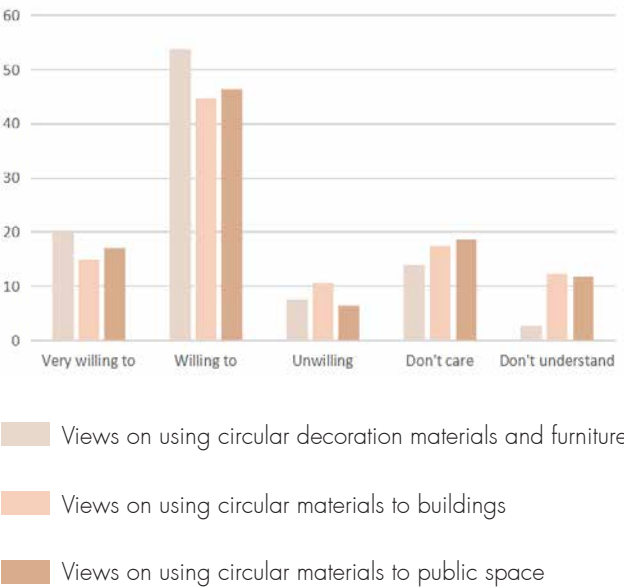
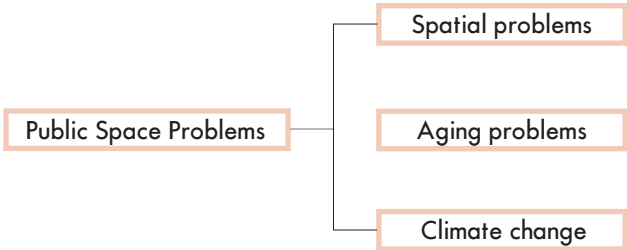


Fig. 5.12 | Views on circular construction

5.4 PUBLIC SPACE PROBLEMS

After several times of regeneration, the overall living quality in the estate has improved. Most of the regeneration of the estates are under rigid demand, that is, changing the most urgent problems. For example, changing the interior layout and replacing the infrastructure, construction equipment, etc. Or the transformation of the facade based on the appearance of the city. There are few measures for improving demand, that is, regeneration of public spaces.

During the investigation, some problems were found, such as the low quality, amount, and usage of public space. We can, therefore, come to the conclusion that although the essential living quality has been improved, the regeneration did not take the improvement of public space into account, the open space, and the quality of public life even decreased.



In the following sections, the problems of public space will be described from three aspects: space problem, aging problem, and climate change.

5.4.1 Spatial problems

1. Lack of public space

Most of the new workers’ estates are arranged in row style. The outdoor public space is located on the open space between the front and rear rows of buildings, with the road in the middle and simple greening on both sides. Since the space between buildings is not very large. Excluding the middle road area, there is very little remaining space available for setting up the public space on both sides, as shown in Fig.5.13.(1).

2. Low quality of public space

Most existing public spaces of new workers’ estates have low quality, and there are very few facilities for people to identify, relax, and having activities. Smaller or older estates have few existing facilities; the service facilities of larger communities have a short service radius, and sometimes the paving and facilities have been damaged. And even if some communities have added activity facilities, they are idle because of low quality, unreasonable location, and layout, see in (2)(3).

3. Homogenization of public space

The type of public space is very simple in the new workers’ estates, and the definition of private space, semi-open space, and open space is weak. There is almost no spatial change in public space. The form and size of each public space are similar. The landscape greening is monotonous, usually with the sidewalk trees and a little green space on both sides of the road. Without well-formed landscape nodes and central event venues, attractive outdoor public space cannot be formed, see in (4).

4. Chaotic walking and vehicle organization

Most of the existing new workers’ estates are lack of space and cannot create a walking free space to ensure walking safety. It is often a mixed traffic mode of people and vehicles. Since the sidewalk is relatively narrow, and the sidewalk trees and car parking occupy part of the sidewalk area, most residents are walking on the roadway, there are hidden dangers, and the safety is inferior, see in (5)(6).

5. Low usage of public space

Not only the greening rate of most public spaces is very low, but most of the greening is also street trees and buffer landscapes, the available space is narrow. Secondly, even if there are relatively many green areas in some estates, these green areas are more emphasized on the role of aesthetics when planning, focusing on the visual appreciation. The green spaces are surrounded by fences or raised from the ground level, where people cannot use them. The result is to have a large area of pure viewing green space, and there is very little activity space that can really serve the residents and can be used by the residents, see in (7)(8).

6. Poor management of public space

The management of public spaces in many new workers’ estates is chaotic, and other functions occupy the venues that should be provided for residents’ activities. For example, public spaces are occupied by bicycles and cars. Many households privately expand their houses, build vegetable gardens to occupy the public space, as shown in (9).



Fig. 5.13 | Spatial problems of public space



Fig. 5.14 | Aging problem of public space



Fig. 5.15 | Flooding problem of public space

5.4.2 Aging problems

In 2018, the "Monitoring Statistics of the Elderly Population and Aged Care in Shanghai" shows that the population of people over 60 years old reached 5.0328 million, accounting for 34.4% of the total population; and the population of people over 65 years old and older was 3.369 million, accounting for total population 23% (Shanghai research center on aging, 2019). Shanghai is one of the cities with the highest aging rate in China, and the new workers' estates have a higher aging rate, which is twice the average of Shanghai (Wang Weiqiang, 2020).

With the development of the social economy, people's demand for living quality has improved. The environment of such new workers' estates has become more and more ruined, and the disadvantages of residential housing types have gradually emerged. Many young people moved out to set up other families, and most of the remained residents are elderly people who are accustomed to living here or have no purchasing capacity, which is the reason why the phenomenon of aging is particularly prominent. (Jin Yunfeng, 2019)

During the construction of these new workers' estates, solving the housing problem is the primary task. The existing public spaces and public facilities cannot meet the increasing needs of residents' living quality (Tu Huijun et al, 2018). At that time, the phenomenon of aging was not fully highlighted, and the problem of aging was not taken into consideration. As the aging of the community became more and more serious, the existing public environment and facilities could no longer meet the needs of the elderly population, and the public space urgently needs elderly adaptive regeneration.

A. Leisure	A 1. Entertainment	Singing/ Chess/ Cardgame/ Musical instrument
	A 2. Exercise	Dancing/ Taichi/ Fitness equipment
	A 3. Reading/ Listening	Reading newspaper/ book/ Listening to the radio
B. Social	B 1. Chat	
	B 2. Greet	
C. Remain	C 1. Rest	Rest/ Meditation/ Bask
	C 2. Observe	People/ Landscape
	C 3. Wait	
D. Housework	D 1. Accompany	Children/ Pets
	D 2. Outdoor housework	Planting/ Drying clothes
E. Deal	E 1. Shopping	
	E 2. Service	Restaurant/ Hospital/ Nursing home
F. Move	F 1. Passing	
	F 2. Exercise	Walking/ Jogging

Table. 5.4 | Material flows in urban scale

Public space for elderly activities

Old people use public space for a longer time. To make an elderly adaptive regeneration, it is necessary to design the public space according to the activities of the old people. As shown in Table 5.4, it lists the common public activities of the elderly by field investigation and literature review.

The activities of the elderly are divided into six categories, including leisure activities, social activities with other people, staying somewhere, housework activities, shopping and service activities, and moving activities. The specific behaviors in each type of event are listed in the table.

5.4.3 Climate change

As the climate changes in global warming, future precipitation is likely to increase. Due to the rapid urbanization development in Shanghai, there are too many hard impermeable pavements. When concrete is poured over green space, the city loses the capacity to absorb water. In the old urban areas of the city, such as new workers' estates, there is a phenomenon that the design standard of the drainage pipe network is not enough for the current situation, and the pipe diameter is small, so the actual drainage capacity is insufficient. When faced with heavy rain, the urban drainage system is overwhelmed, as shown in Fig. 5.15.

Due to the higher risk of flooding caused by climate change, public space regeneration should be carried out to mitigate the effects of flooding caused by climate change.

'Sponge city' is an urban design method that has been used in recent years. 'Sponge City' means that through strengthening urban planning, management and construction, the building, roads, green spaces, water systems, and other ecosystems can give full play to the absorption, storage and slow release of rainwater. It effectively controls rainwater runoff and achieves natural accumulation, natural infiltration, and natural purification (Yu Kongjian et al, 2015). Because it has good flexibility in adapting to environmental changes and responding to natural disasters by rain, it can also be called "water flexible regeneration".

Sources:
<http://xs.cnnb.com.cn/system/2013/10/10/010757221.shtml>

5.5 CONCLUSION

- Current regeneration of buildings

- Current regeneration of the new workers' estates is always focusing on building regeneration, including structure and Interior layout regeneration, facade regeneration, and facility and infrastructure regeneration.
- The property right of buildings have the opportunity to change for regeneration. The participation of residents is in a relatively low level. The source of funds is single and insufficient.

- Material flow of different regeneration

- The regeneration material flow mode can be divided into three categories: Demolition, Refurbishment, and Maintain.
- The demolition mode has a great number of materials flow out and flow back.
- The refurbishment mode has a lower number of materials flow out and flow back.
- The maintain mode has materials flow in.
- This is a complex process that includes multiple categories of materials, various sources, various destinations, and numerous processing methods. Therefore, a network is needed to enable multiple processes to be coordinated and managed to improve the efficiency of circular construction.

- Evaluation

- Through investment, the public space is the most dissatisfied part of the new workers' estates, and it is also the strongest part of residents' willingness to regenerate
- People have the least knowledge of using circular materials on buildings, and some people are entirely refuse to live in such buildings. Applying circular materials to public spaces could be an ideal transition step for the promotion of circular construction. Select pilot projects for experimental popularization, and gradually make users accept this new regeneration method.

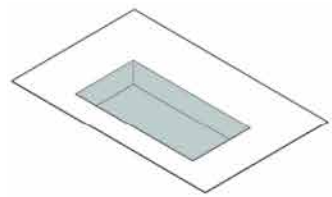
- Public space problems

- Spatial problems
- Aging problems
- Climate change

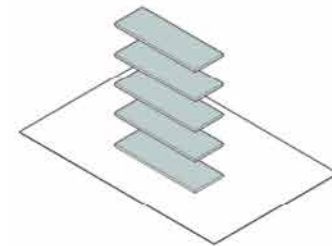
6

CIRCULAR REGENERATION

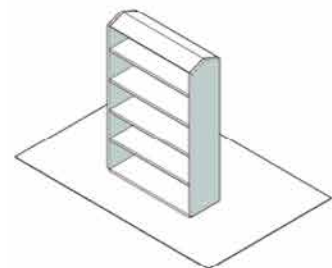
6.1 BUILDING MATERIALS



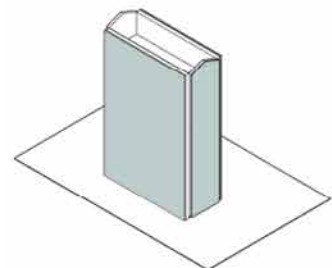
Base - construction mud



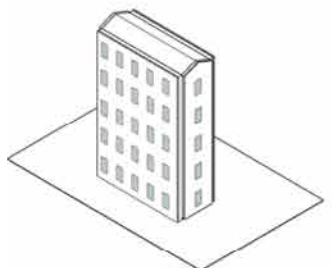
Floor - concrete and metal



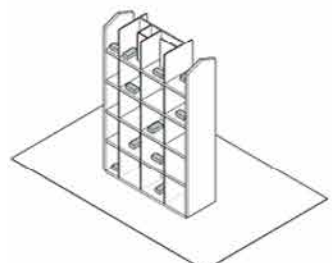
Structure - brick



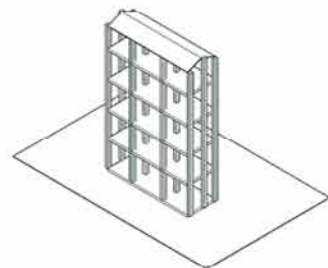
Exterior wall - brick



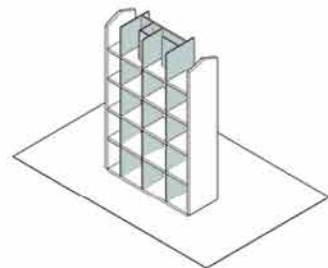
Windows



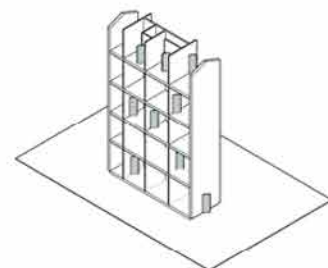
Interior decoration and furniture



Structure - concrete and metal



Interior wall - brick and concrete



Doors

6.1.1 Material from buildings

Different parts of the building are made of different materials. The main building components that are easy to be reused and recycled include base, floor, structure, wall, window, door, interior decoration, and furniture.

The construction waste of base is construction mud, which accounts for a large part of CDDW.

For other components, the amount of waste generated during demolition is much greater than during construction. The waste generated varies according to the structure of the building. There are two main types of building structures in new workers' estates. The old multi-story building structure is brick and concrete. The structure of the later high-rise building with more than six floors is reinforced concrete.

No matter what kind of structure, brick, and concrete are the most used materials in new workers' estates construction, and they are also the most wasted materials.

In addition to them, there are doors and windows, as well as interior decoration, furniture, which are decoration waste composed of complex materials.

6.1.2 Classification of materials

The building materials of the building are complex and numerous. Different building materials have different potentials for recycling and are processed differently. These materials are divided into three categories- aggregate, component, and module, based on the complexity of the composition and the difficulty of circular use.

The aggregates, in most cases, cannot be reused directly to the new construction process. They need to be crushed, separated, and then processed into new building materials.

The components can be reused after maintenance. Sometimes, when the component is severely damaged, it can also be split and processed into secondary materials.

The module is a combination of various components and products.

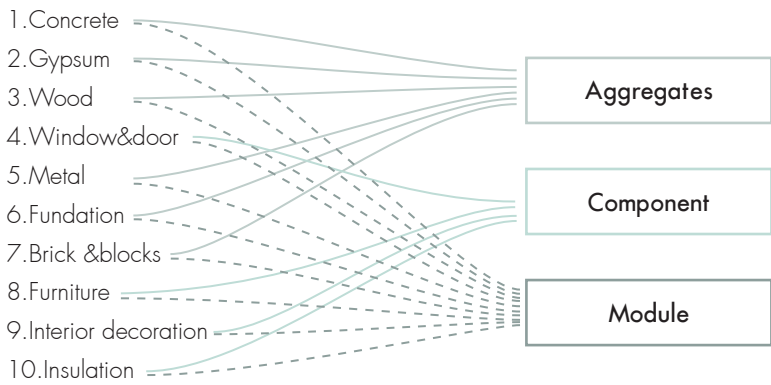
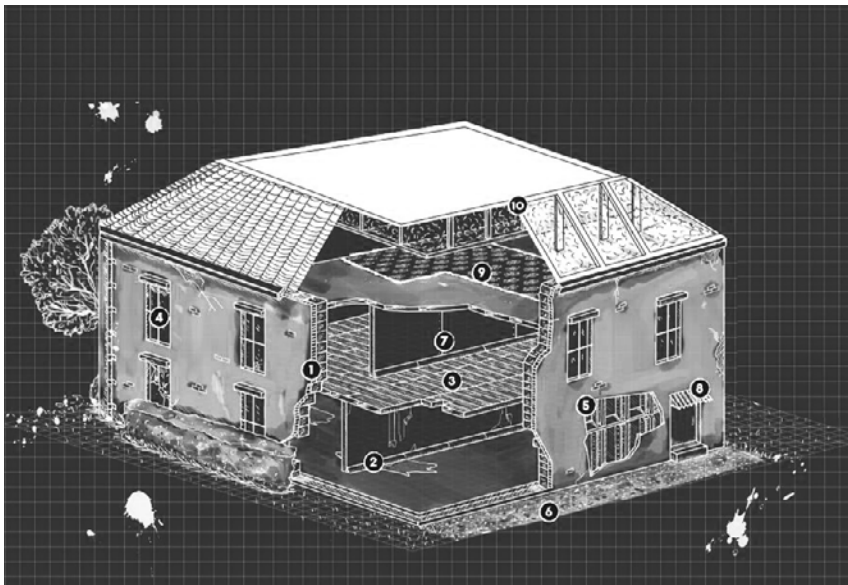


Fig. 6.2 | Classification of building materials

Fig. 6.1 | Materials from buildings

Sources:
<http://rubberbond.co.uk/blog/recycling-buildings-10-building-materials-that-can-be-reused-after-demolition/>

6.1.3 Material Generated in Regeneration

According to the source of CDDW, it is mainly generated during the process of construction, decoration, and demolition. The main components and proportion of elements in the three types will be discussed below. In addition to these wastes, the construction process involved in urban renewal needs to consume new materials, which will also generate wastes when they are manufactured. According to the data, the total material flow in the future can be predicted (Yu, B. et al., 2019).

Construction waste

In the construction process, the contents of various components of waste generated by buildings of different structural types are different. But the main components are the same, mainly scattered mortar and concrete, brick and concrete fragments, scrap metal, bamboo and wood, various packaging materials, accounting for about 80% of the total CCDW, and other waste components account for about 20%. Table 6.1 lists the proportion of construction waste of brick concrete structure and reinforced concrete structure. According to the rough statistics of the loss of construction materials from brick and concrete structure and frame structure regeneration, in the construction process of every 10000 square meters of building, the amount of construction waste is 500-600 tons (Zhu Dongfeng, 2010). In the early time, the use of building materials was more frugal, so take the minimum amount, that is, 0.05 tons per square meter. From this, the amount of waste generated per unit construction area of construction wastes during construction is calculated, as shown in Table 6.2. and Fig.6.3.

Waste component	Waste composition ratio(%)	
	Brick and concrete structure	Reinforced concrete structure
Brick	30-50	15-30
Sand	8-15	10-20
Concrete	8-15	23-45
Packaging	5-15	5-20
Roof	2-5	2-5
Steel	1-5	2-8
Wood	1-5	1-5
Others	10-20	10-20

Table 6.1 | Component of construction waste (Wu Xianguo, 2003)

Waste component	Amount of waste(kg/m²)	
	Brick and concrete structure	Reinforced concrete structure
Brick	15-25	7.5-15
Sand	4-7.5	5-10
Concrete	1-7.5	11.5-22.5
Packaging	2.5-7.5	2.5-10
Roof	1-2.5	1-2.5
Steel	0.5-2.5	1-4
Wood	0.5-2.5	0.5-2.5
Others	5-10	5-10

Table 6.2 | Amount of construction waste

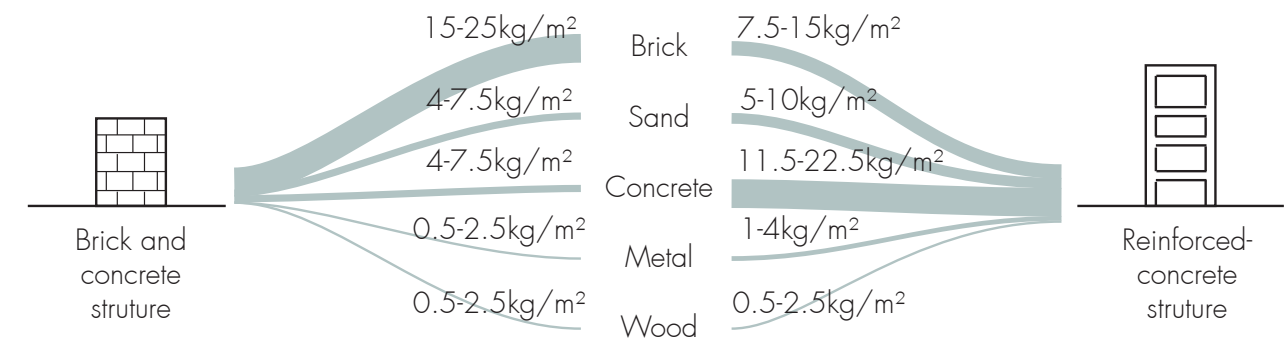


Fig. 6.3 | Waste materials of construction

Demolition waste

Compared with the construction process, the amount of waste generated in the unit area from the demolition of old buildings is more significant. The composition of the demolition waste of old buildings is related to the structure of the building: in the old brick concrete structure building, brick, and rubble account for about 80%, the rest are wood, broken glass, lime, slag. The old multi-story houses that may be demolished in this study are mostly brick-concrete structures. For the old reinforced concrete structures building, the concrete blocks account for about 50% - 60% and the rest are metal, brick, block, plastic products. In this study, the high-rise old public houses with more than six floors that may be demolished are all reinforced concrete structures. In the 1960s, statistics from a residential development company in China showed that 1.35 tons of demolition waste was generated per square meter of housing. Table 6.3 is Chen Jun's reference data on waste generated per square meter of building demolition (Chen Jun, 2007). In the table, the waste generated after the demolition of brick-concrete residential buildings is about 1.3t / m², and the waste generated after the demolition of reinforced concrete residential buildings is about 1.8t / m².

Waste component	Amount of waste(kg/m²)	
	Brick and concrete structure	Reinforced concrete structure
Brick	400.8	233.8
Concrete	894.3	1494.7
Glass	1.7	1.7
Steel	13.8	18
Others	25	25

Table 6.3 | Amount of demolition waste

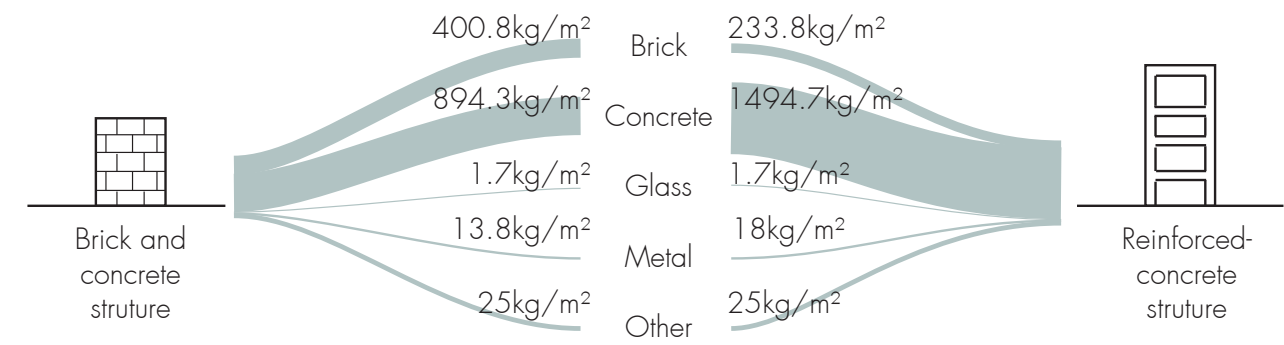


Fig. 6.4 | Waste materials of demolition

Decoration waste

The composition of decoration waste is relatively complicated and contains a certain amount of toxic and harmful substances. Among them, 29.8% are recyclable, 49.2% are non-recyclable, and 21% are ash (Figure 5.13). Recyclable materials include natural wood, paper packaging, small amounts of masonry, concrete, mortar fragments, steel, glass, plastic.; non-recyclable materials mainly include adhesives, glued wood, waste paint, and their packaging (Li Yanqiong, 2006). According to experience, the amount of decoration waste in residential building units is 0.1 t / m². In addition, according to the research results of Niu Jia et al., the decoration of each house produced about 2 tons of decoration waste.



Fig. 6.5 | Component of decoration waste

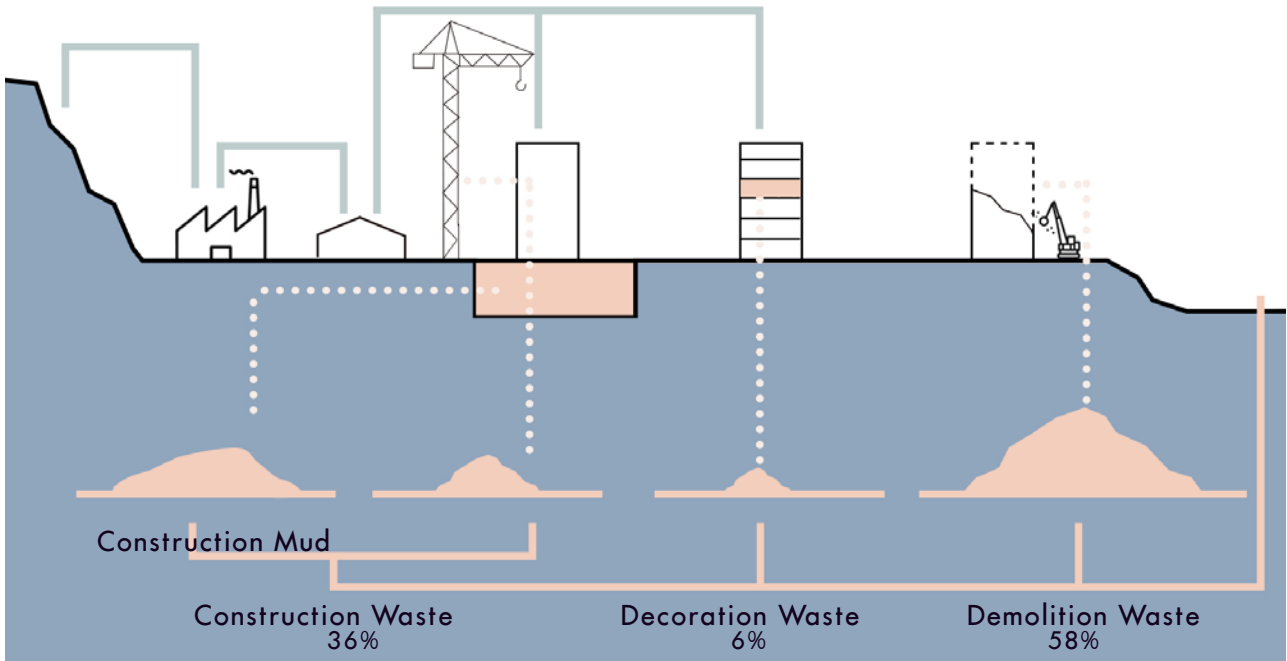


Fig. 6.6 | Component of CDDW

All in all, as shown in Fig 6.6, the demolition waste takes the most proportion of CDDW, which is 58%, contains almost all kinds of waste materials. The construction waste takes a proportion of 36%, while most of the construction waste is the construction mud from the foundation. The amount of other waste materials from the construction process only takes a small amount. Decoration waste only accounts for 6%. Although the quantity is small, there are many kinds, the materials involved are complex, and it is difficult to recycle and reuse (Zhu Dongfeng, 2010).

Therefore, the main materials for circular use are the waste building materials from the demolition process and the construction mud. How to make circular use of decoration waste is also a significant problem that needs to be solved.

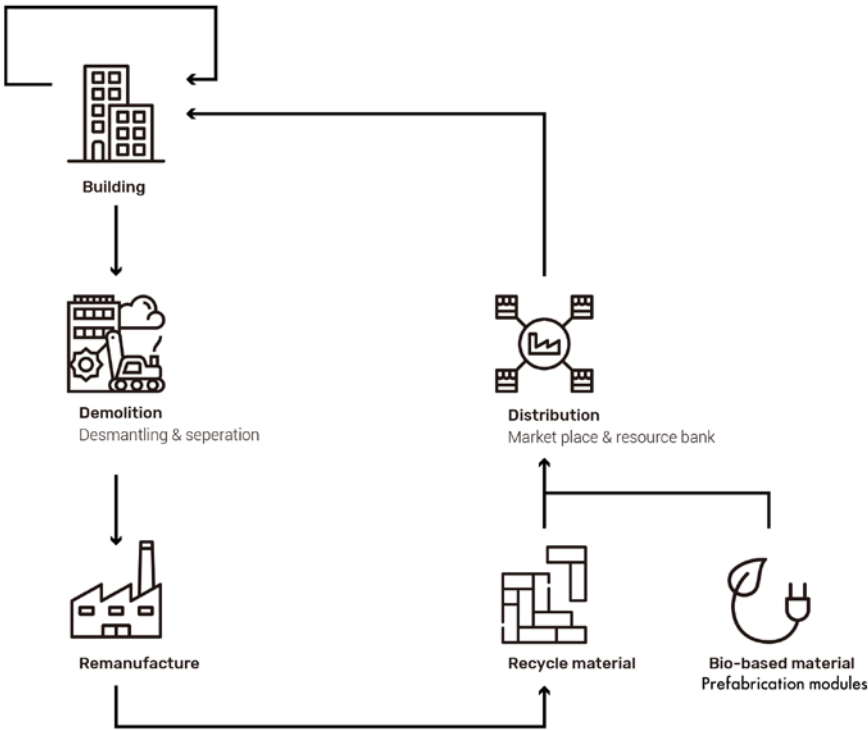


Fig. 6.7 | Circular construction chain

6.2 CIRCULAR USE OF BUILDING MATERIALS

According to the current construction flow, building, demolition, remanufacture, bio-based material, and distribution were addressed as the main steps in the chain for closing the construction loop, as shown in Fig. 6.7.

This relates to several steps:
Demolition: dismantle buildings in crisis and separate high-quality materials.
Remanufacture: combine the existing industry with the process of high-value construction materials.
Production of sustainable materials: use bio-based materials and prefabricated modules, which are easier to be reused, and the recycling process will be more eco-friendly.
Distribution: establish a platform for diverse material collection and find more preferable modes of transportation.
New estate design: use a modular design, flexible design, low

material design to reduce material consumption and make the future construction process more easily to be circularly regenerated (Riera Pérez, 2018).

As shown in Figure 6.2, because different types of building materials have different recycling technologies, recycling technologies are divided into three types: recycle technology for aggregates, recycling technology for components, and recycle technology for modules. Most of the aggregate technology is to separate and crush the aggregate and then reprocess it to form new building materials. The technology for components is to dismantle the components as a whole, and then directly reuse them after maintenance. The technology for modules includes the removal of an entire module in a common brick-concrete structure or a reinforced concrete structure building and the technique of applying a modular house.

	Material type	Product	Stimulating factors	Blocking factors
Aggregate	Concrete	Staircase	Can be reused for landscape	Comparative low cost of new products
		Structural products (columns, beams, frames)	Need more experiments with cascade reuse	Large size components have complex for demolition. Small market demand. Cost to handle and equipment may be a barrier for cascading.
		Concrete floor tiles	Easy for reuse	Cheap price for new component
		Concrete roof tiles	Need more experiments with cascade reuse	Cheap price for new component
	Bricks	Wall brick	Easy for reuse	Comparative low cost of new products
		Surface brick	Easy for reuse	Comparative low cost of new products
	Metal	Structure	Require complex steps to be reused	Harmful substances in sprayed products are not conducive to reuse. Although it is an appreciated component to be recovered and sold in the market, it is not commonly found in the housing segment.
		Plywood	Cascading reuse possible	Harmful substances in sprayed products are not conducive to reuse.
		Laminated floor	Cascading reuse possible	Vulnerable to damaging during demolition
		Forms for concrete in situ	Cascading reuse possible	Risk of contamination by use of reactive concrete release agents
Component	Construction mud	Base	Can be reused for backfilling and landscape	Comparative low cost of new products
		Window and doors	Can be reused after maintenance	Comparative low cost of new products
		Furniture	Mostly be reused informally	Cheap price for new component
Module	Infrastructure (pipes, instruments)		Can be reused after maintenance	Vulnerable to damaging during demolition
			The construction technology applied makes it difficult to be completely split	Cost to handle and equipment may be a barrier for cascading.

Table. 6.4 | Reuse potential of materials (Loriane, 2019)

6.2.1 Reusability of materials

Different building materials have different possibilities of being circular used. The various materials that make up the buildings are evaluated, and their potential for circular construction is analyzed (Loriane, 2019).

For aggregate building materials, the products made of this material are listed in Table.6.4, the ease of circular use, and other factors affecting reuse are evaluated.

- The current techniques for concrete recycle are mainly down-cycled to landscape or being used as the base. But the raw materials that replaced by these materials are cheap and easy to obtain, so this way of recycling is not probably better than using raw materials.

- More concrete components, such as floors and structures, require more research and experiments if they are to be used again in buildings or public spaces. The recycling process is complex and needs a lot of equipment. To achieve their recycling requires balancing the benefits of sustainable development with the cost. In any case, concrete is one of the largest proportions of building materials, and it needs to be recycled.

- Bricks are easier to reuse than concrete, but the price of raw bricks is also very low. Therefore, the cost of reuse needs to be controlled.

- The products of metal in buildings are mainly structures, which are usually poured with concrete, which means that disassembly is difficult. In general, secondary metal materials are widely used. Due to safety considerations, it is not common to use them in construction again.

- According to research (Loriane, 2019), wood is the material most likely to be cascading reused. However, the use of wood in new workers' estates buildings is very small. Therefore, in the regeneration process, the use of wood or other bio-based materials should be increased.

The components are most probably to be reused. The current reuse of furniture is mainly informal, and the reuse efficiency is relatively low. Residents' perceptions of the use of secondary materials need to change.

When the technology meets certain requirements, some modules of the old building can be completely removed and directly applied to the new building. This circular construction technology is difficult to apply to buildings that are already built. However, when designing a new building, consideration should be given to facilitating the application of this technology in the future.



Fig. 6.8 | Circular aggregate materials



Fig. 6.9 | Bio-based materials



Fig. 6.10 | Circular components



Fig. 6.11 | Circular use modules from common buildings

Sources:
<http://www.stonecycling.com>
<http://news.bio-based.eu/home-sweet-home>
<https://www.superlocal.eu/bouw-drie-circulaire-proefwoningen-van-start/>

Aggregate		Recycle method
	Brick	Recycled bricks
	Concrete	Recycled concrete/ brick
	Metal	Reuse/ Recycle
	Wood	Plywood

Table. 6.5 | Recycle methods of aggregates

	Original material	Secondly-raw material	Reused products
Aggregate Reuse	Brick		Brick
			Partition filler
	Metal	Steel	Gallery/Partition
		Steel bar	Sculpture/Partition
		Metal components	Sculpture
	Mud		landscape
	Wood		Wood

Table. 6.6 | Reuse methods of aggregates

6.2.2 Circular construction methods

The conclusion from the previous section is that the aggregates which contain construction mud, brick, concrete, metal, and wood are the materials that can be recycled most probably. The components and modules can be reused. In this paragraph, discuss how these materials can be recycled and reused.

For aggregates, most of them can only be recycled after crushed, separated, and then processed into new building materials.

- When new workers' estates buildings are demolished, a large number of waste bricks will be generated. These materials will significantly reduce the strength if they are mixed in concrete. They can be broken after separation to make recycled bricks, building blocks, and floor tiles, as shown in Fig.6.8.
- Waste concrete is an essential part of construction waste, and it is also a component with higher recycling value. After crushing, washing, and grading, concrete blocks are mixed at a certain ratio to form recycled aggregate (WCA), which can be used to produce recycled concrete and recycled brick (Hu Weifan, Zhang Zixue, 1993).
- After the preliminary crushing of the reinforced concrete block, the iron contained in it is removed by a magnet, and the remaining steel is separated from other materials and can be reprocessed and reused.
- Waste wood dismantled from buildings can be made into plywood by adding adhesive.

In addition to aggregates that cannot be reused directly, concluded in Table.6.5, some materials can be directly reused

under specific processing methods (Esa, M. R., et al. 2017), concluded in Table.6.6.

- Completely demolished bricks from the building can be reused directly. Some broken bricks can be reused as a filler for partition walls
- The steel can be reused for gallery or partition. The complete steel bar separated from the concrete can be used as a support for landscape partition walls or sculpture. Some small metal components can be reused as the material of sculpture,
- The construction mud from the base of the new buildings can be reused for backfill or reused to shape landscapes with varying elevations, or soil for planting.
- The waste wood generated from the construction, decoration, and demolition process can be directly reused according to the size after removing the surface pollutants. It can be processed into stairs, railings, interior floors, decoration, and furniture.
- In addition to reusing the small amount of wood in existing buildings, the use of bio-based materials should increase during the regeneration process, as shown in Fig.6.9.

The components and modules can be reuse as Fig.6.10 and Fig. 6.11 shown. From the experiment of 'Superlocal,' they dismantle three modules from a normal reinforced concrete structure apartment and build new labs by using them.

6.2.3 Circular rate of building materials

The recycling rates of aggregates are shown in Table.6.7. It shows the recycling process from the original material to secondary material and the proportion of waste material and raw material of recycled products made from these secondary materials.

The data comes from implemented projects and experimentally verified conclusions.

	Original material	Secondly-raw material	Recycled products	Waste material propotion	Raw material propotion
Aggregate Recycle	Brick	Wall brick	Brick	60-80%	20-40%
			Building block	50%	50%
		Floor brick	Ground brick	60-80%	20-40%
			Permeable brick	30%	70%
		Concrete	Concrete	85%	15%
	Concrete	Stone	Artificial stone	-	-
			Concrete	70%	30%
		Structure concrete	Recycled Aggregate Block	85%	15%
		Downcycle concrete	Concrete	100%	-
		Stone	Artificial stone	-	-
	Metal		Rebar/ Steel	100%	-
	Wood		Plywood	-	-

Table. 6.7 | Circular rate of aggregates

There are many experimental studies and practical applications related to the recycling of bricks. Take WasteBasedBricks (Stonecycling, 2018) as an example. They manufacture high-quality building materials made of waste materials, including wall bricks, ground bricks, and facing bricks, made of a minimum of 60% waste materials. When a certain production amount is reached, energy consumption is reduced by 25%. The produced bricks have good durability and load-bearing function. This type of technology can already be used in actual project construction.

There are also some experiments on recycling the waste bricks into larger concrete building blocks, 50% of materials used in manufacturing are waste bricks. Compared with blocks made of new materials, the strength of secondary blocks has decreased, and with the increase of the replacement rate of recycled crushed brick aggregates, the strength of the blocks decrease. The 50% broken brick aggregate replacement rate has the highest block strength, but still not suitable for excessive weight-bearing (Zhu Xiu, 2016).

Recycled aggregates of waste bricks after sorting, crushing, and sieving can directly be used to manufacture non-burning water-permeable bricks. 30% of the materials are secondary materials. These bricks use recycled materials while reducing emission and be permeable (X. Shen,2018). Waste bricks can also be used to make brick-slag light-bone concrete. The content of the brick slag is 85%. This technology has been successfully applied to the construction of building roof structures (J. Liu & Y. Yao, 2019).

Recycled aggregate concrete can be made from recycled aggregate formed by crushing waste concrete. When the

replacement rate of secondary material is 50% and 100%, the early strength of recycled concrete is slightly higher than that of ordinary concrete. In contrast, the later strength decreases more than regular concrete. The strength change of the recycled concrete with 70% replacement rate is similar to that of ordinary concrete, and the strength is about 95% of that of ordinary concrete (S. Gu, T. Lei & J.Tao, 2012). The strength of recycled materials still needs to be enhanced as technology develops.

Recycled aggregates made from waste concrete can also be used to make recycled concrete hollow blocks. When the mix ratio is reasonable, and the replacement rate of recycled coarse aggregates is increased to 85%, the conversion strength of recycled aggregate concrete hollow blocks can be up to 7.6 MPA, and conversion strength level can reach MU5.0 requirements (L. Zhuo & B.Chen, 2014), but this is the minimum standard of conversion strength level (the use of light aggregate concrete hollow blocks with a strength level lower than MU5.0 is prohibited in building construction projects), which means more experimental exploration is still needed for widely used in construction.

To make it simple, most of the construction and demolition waste from the construction is currently being down-cycled within the infrastructure sector, used as a landfill, namely 95% (Rijksoverheid, 2015). The down cycle can make 100% circular use of the waste materials. However, the circular use method like this did not fully realize the waste's value. Therefore, in addition to the harmless waste materials that the technology is still unable to deal with at this stage can be treated in this way, in other cases, minimize the use of this method.

Recycled steel bars can be made from waste metal after selection, shearing, processing, heating, rolling, and natural cooling. Almost 100% of scrap metal can be used as raw materials. However, there are higher quality requirements for scrap metal (DB34/T 1016-2009). In fact, metal recycling is more widely used, but the proportion of recycled materials used in construction is small.

In conclusion, under the current techniques, the proportion of waste materials in the process of manufacturing recycled materials is already relatively high. However, there is still much room for improvement in the strength of the recycled materials.

6.3 CIRCULAR MATERIAL & PUBLIC SPACE

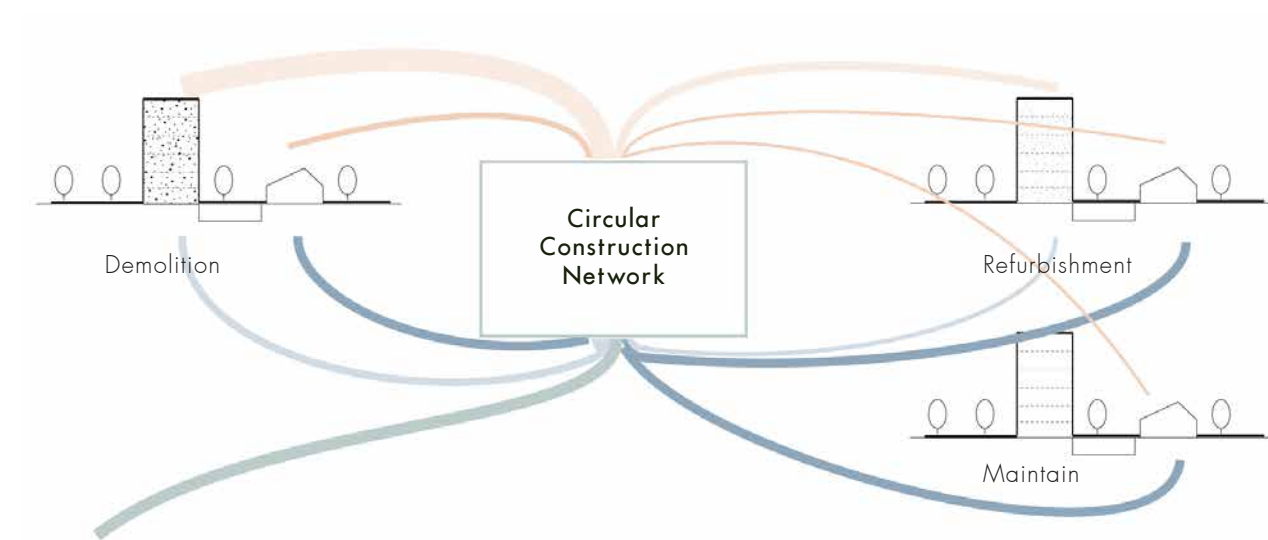


Fig. 6.12 | Circular material flow and public space

As mentioned in the last section, the current circular construction techniques cannot be widely used in building construction. The strength of some of the secondary materials is not enough to support the building. According to Chapter 5.3, the public space problem of the new workers' estate is as severe as the buildings'. Materials used in public spaces have lower strength requirements than buildings. Therefore, it is a great opportunity to use the circular material in the regeneration of public space in the new workers' estate.

Combined with the three types of new workers' estates, the material flow between the new workers' estate is as shown in Fig. 6.12. A large number of materials flow out from the Demolition estates, and some materials flow out from the buildings and public space of Refurbishment estates. Only a small amount of materials flow out from the public space of Maintain estates. After the reuse and recycling process through the circular construction network, a large proportion of the secondary materials are used for the improvement of public space. Meanwhile, use bio-based materials in the re-construction process.

- Building materials flow out
- Public space materials flow out
- Building materials flow in
- Public space materials flow in
- Bio-based materials

6.4 MATERIAL CONSUMPTION OF PUBLIC SPACE

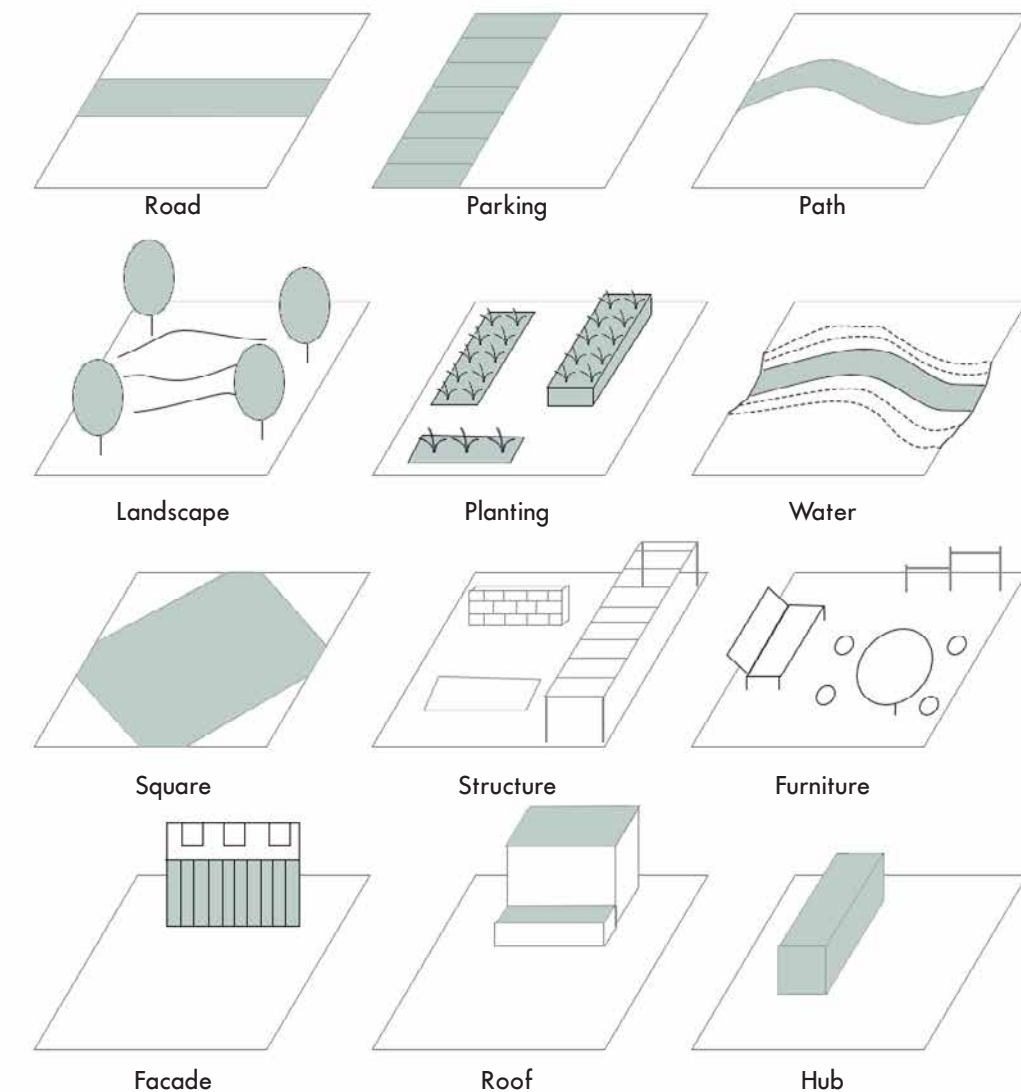


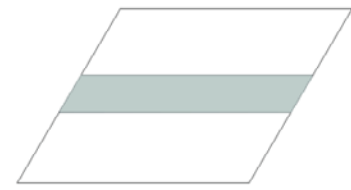
Fig. 6.13 | Types of public space products

6.4.1 Toolbox of public space

The construction of public space is composed of many materials. To understand what materials are needed to regenerate the public space, and how many materials are required, the public spaces are listed to form a toolbox, as shown in Fig. 6.13. The type of materials corresponding to each type of open space product in the toolbox is relatively clear and single, which is more convenient for research.

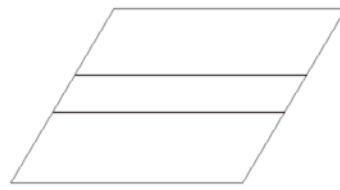
In more detail, the possibility of applying different circular materials to each category of the toolbox is listed in Fig. 6.14. The toolbox shows the material, the proportion of circular material used, the total amount of material used per m², and points to emphasize from a design perspective.

6.4.2 Toolbox-material

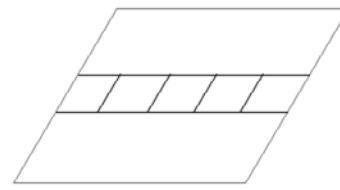


Road

- Material
- x% is waste material
- Material used per m²
- Special design



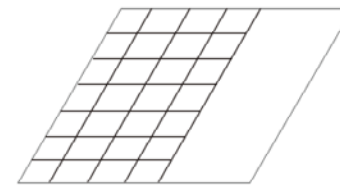
- Recycled asphalt
- 50% is waste material
- 3000kg/ m³
- Permeable



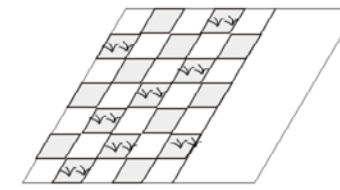
- Recycled concrete board
- 70% is waste material
- 2400kg/ m³
- Permeable and modular



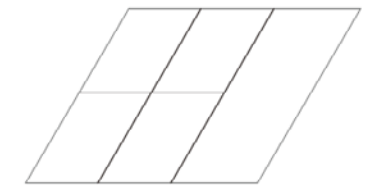
Parking



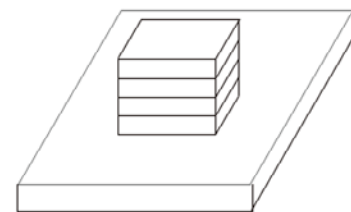
- Recycled brick
- 30% is waste material
- 1800kg/ m²
- Permeable



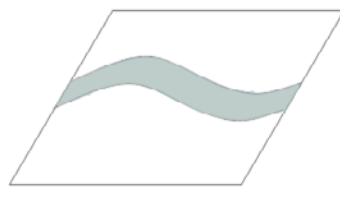
- Recycled brick and mud
- 30% is waste material
- 1000kg/ m²
- Permeable and saving



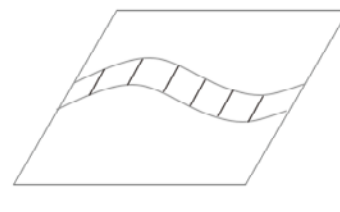
- Recycled concrete board¹
- 70% is waste material
- 2400kg/ m³
- Permeable and modular



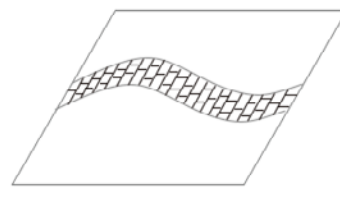
- 3D parking mixed
- 70% is waste material
- 2400kg/ m³
- Saving space



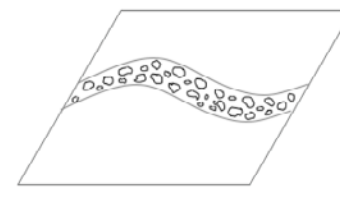
Path



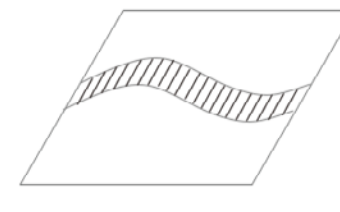
- Recycled concrete board
- 70% is waste material
- 2400kg/ m³
- Permeable and modular



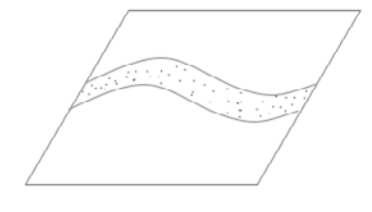
- Recycled brick
- 30% is waste material
- 1800kg/ m²
- Permeable



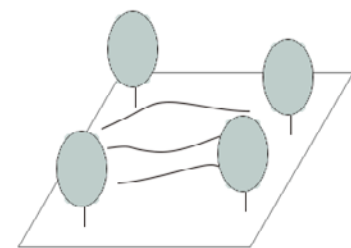
- Reused stone
- 80% is waste material
- 3000kg/ m²



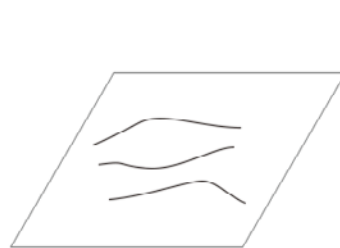
- Wood
- Bio-based material
- 400-600kg/ m²
- Reusable



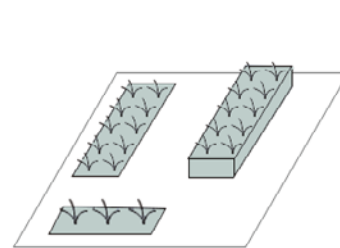
- Plastic and rubber
- x% is waste material
- Healthy and permeable



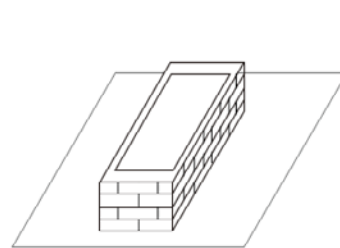
Landscape



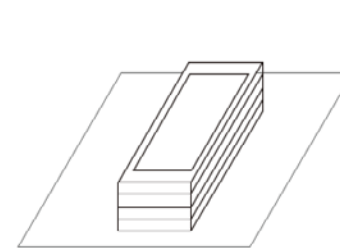
- Construction mud
- 100% is waste material
- 2000kg/ m³
- Aesthetical and fascinating



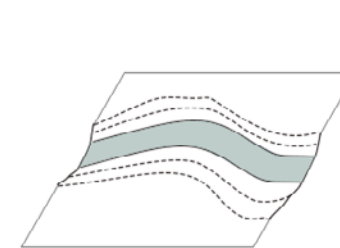
Planting



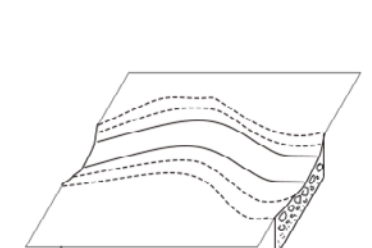
- Recycled/reused brick
- 70% is waste material
- 1800kg/ m²
- Participatory



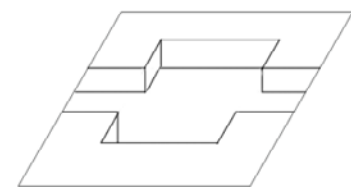
- Wood
- Bio-based material
- 400-600kg/ m²
- Participatory



Water



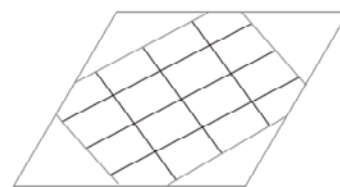
- Slope construction mud
- 100% is waste material
- 2000kg/ m³
- Permeable



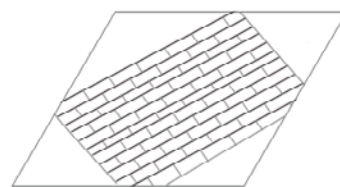
- Artificial concrete
- 70% is waste material
- 2400kg/ m³
- Aesthetical and fascinating



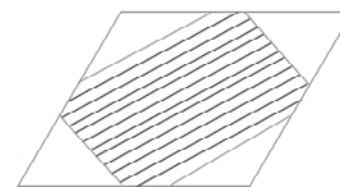
Square



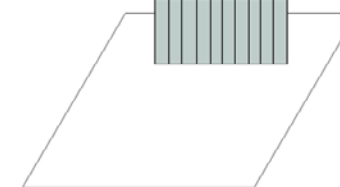
- Recycled concrete board
- 70% is waste material
- 2400kg/ m³
- Permeable and modular



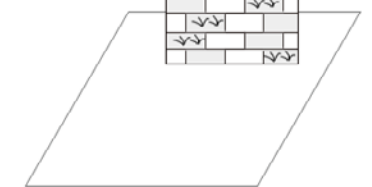
- Recycled brick
- 30% is waste material
- 1800kg/ m²
- Permeable



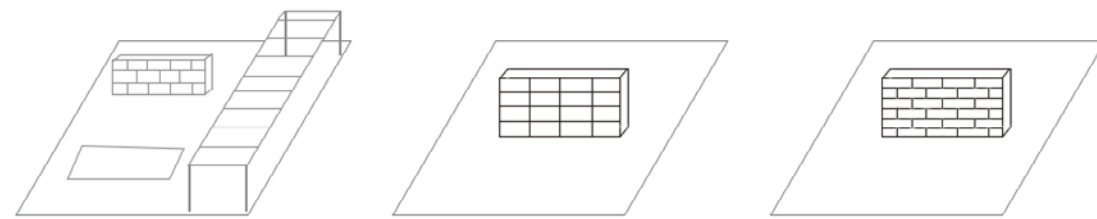
- Wood
- Bio-based material
- 400-600kg/ m²
- Reusable



Facade



- Recycled brick and mud
- 30% is waste material
- 1000kg/ m²
- Micro-climate and aesthetical



Structure

- Recycled concrete block
- 85% is waste material
- 2400kg/ m³
- Recycled/reused brick
- 70% is waste material
- 1800kg/ m²

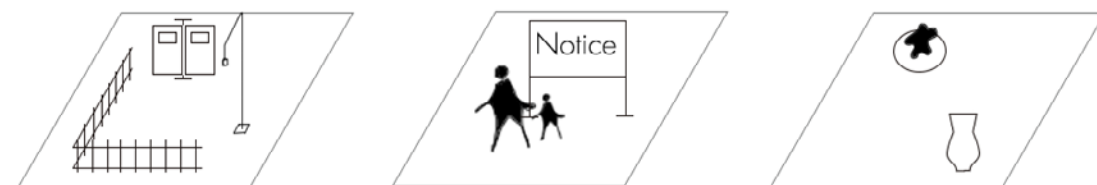


- Reused stone and steel
- 100% is waste material
- Recycled/reused metal
- 100% is waste material
- Wood
- Bio-based material
- 400-600kg/ m²
- Reusable

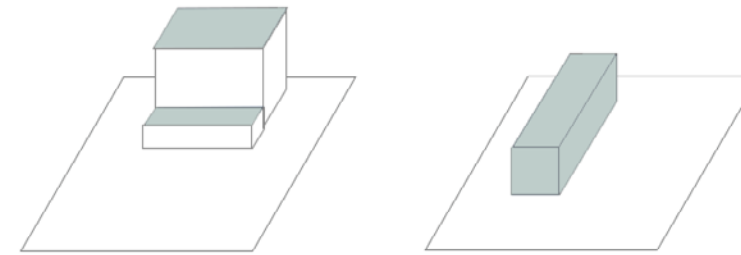


Furniture

- Stay/rest mixed
- Leisure/activituy mixed



- Functional mixed
- Display mixed
- Decoration mixed



Roof

Hub

Fig. 6.14 | Toolbox of circular materials used in public space

6.4.3 Calculation of circular material used in public space

To calculate the number of circular materials used in public space, we need to know how much waste material is produced per unit area of a building, how much material is required per unit area of public space, and how much waste material is needed for the manufacture of this secondary material. Then the area ratio of the building and public space is integrated to calculate the conclusion finally.

The demolition waste is 1300-1800kg/m², construction waste is 50kg/m², and decoration waste is 40-100kg/m². Bricks account for 15%, concrete accounts for 60%. On average, the waste bricks produced per unit area of the building is about 230 kg/m². The waste concrete produced per unit area of the building is about 900 kg/m², as mentioned in 6.1.3.

According to Fig. 6.14, the average material usage of aggregates materials (brick and concrete) is about 2000kg/m³. Assuming that the evaluation thickness of various components is 5-10cm, the material needed per unit area of public space is 100-200kg/m².

As mentioned in Table.6.4, the average usage of recycled waste material accounts for 50-70% of the secondary material. Therefore, the waste material that can be reused per unit area of public space is 50-140kg/m².

In the new workers' estates, the building floor area (S1) always takes 1/3 of the whole area of estates, and the public space (S2) takes 2/3, which means that S1: S2 = 1:2. On average, the new workers' estates have 6 floors, so the whole area of building area (S3) is six times that of S1, as shown in Fig. 6.15. Therefore, S2 : S3 = 1:3.

Finally, take bricks and concrete as the examples, 7-21% of the waste bricks from the original estates can be circularly used to public space regeneration. 2-7% of the waste concrete from the original estates can be circularly used to public space regeneration.

All in all, the material flow in the new workers' estates is shown in Fig.6.16. Aggregates, components, and modules from the original buildings flow to the public space.

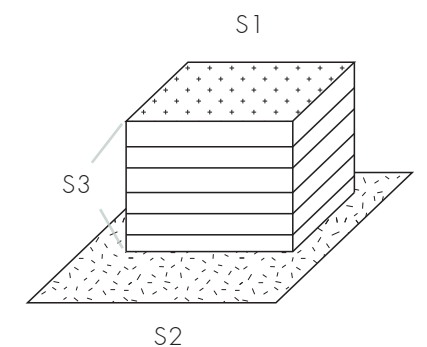


Fig. 6.15 | FSI and GSI of the new workers' estates

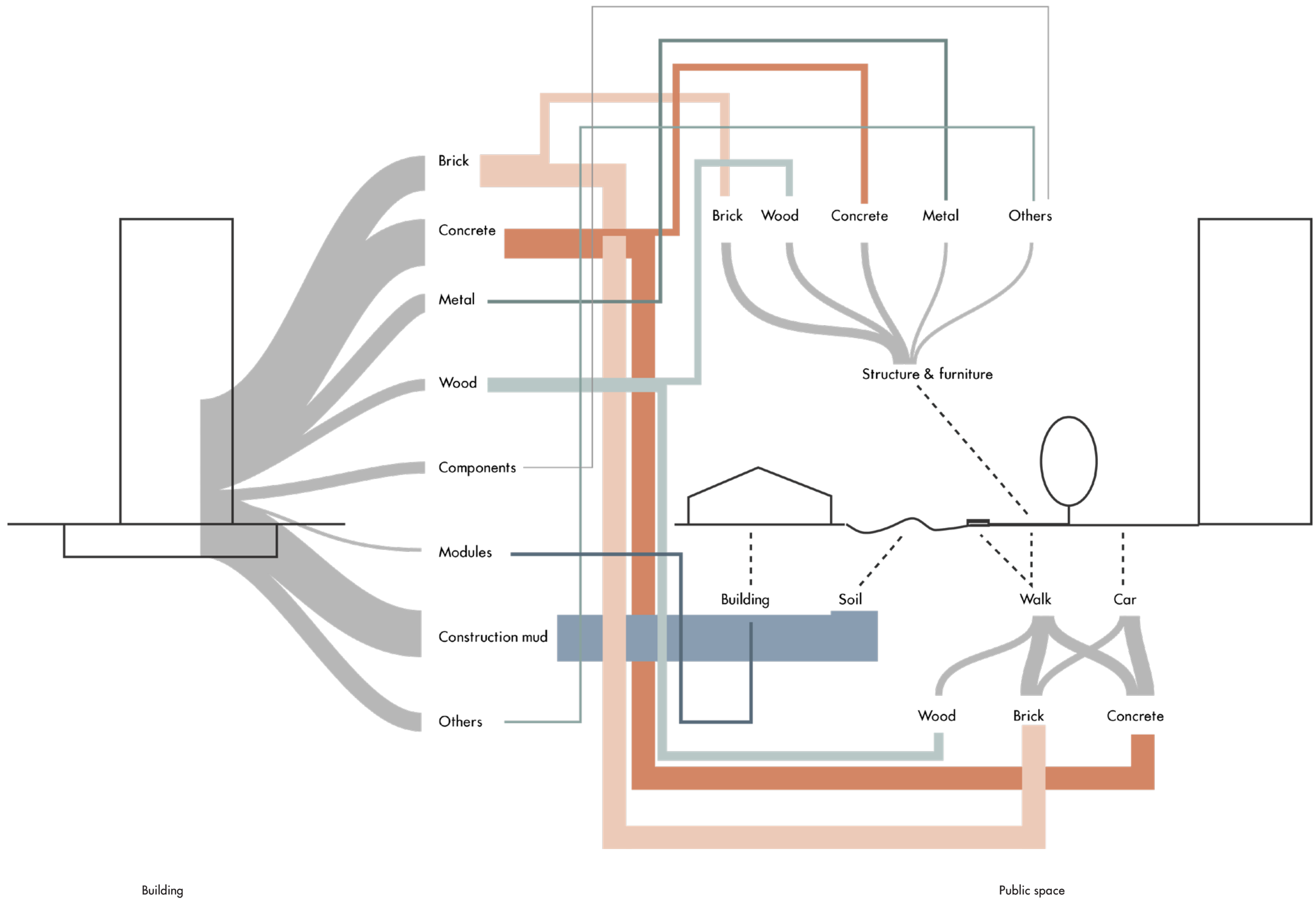


Fig. 6.16 | Material flow from building to public space

6.5 CIRCULAR MATERIAL FLOW

6.5.1 Circular material flow

After the calculation, the circular flows of bricks and concrete are shown as Fig.6.17 and 6.18.

7-12% of the waste brick from building and public space can be reused on-site or recycled off-site to the regeneration of open space, which also means that 50-70% of the materials used in the public space regeneration are secondary materials. According to Shanghai's circular construction goals and technological constraints, 20% of the waste cannot be reused, and the remaining part of them will be reused to other industries.

2-7% of the waste concrete from building and public space can be reused on-site or recycled off-site to the regeneration of public space, 50-70% of the materials used in the public space regeneration are secondary materials. The on-site reuse proportion of concrete is less than bricks'.

The proportion of concrete is lower because the building will consume more recycled materials. If the quality of recycled materials can be guaranteed, their use in buildings is more valuable. The structure of the new building is transforming into reinforced concrete, thus consuming most of the waste concrete.

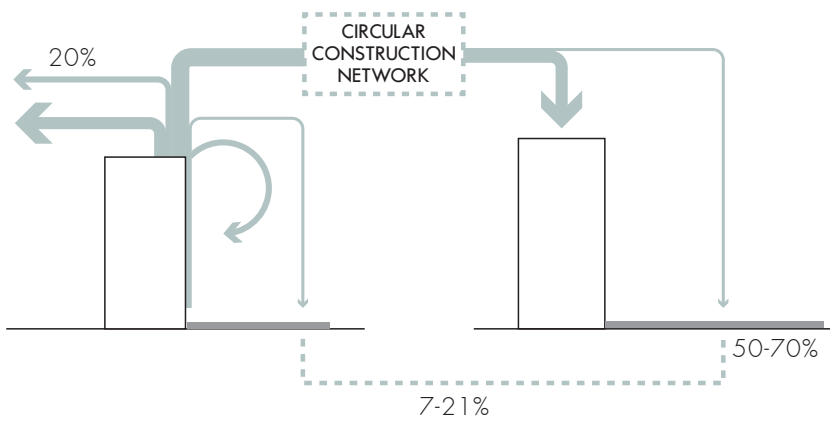


Fig. 6.17 | Circular flow of bricks

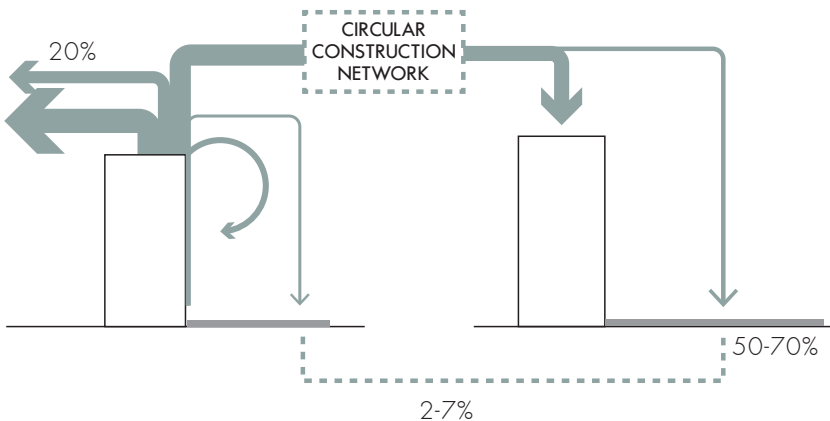


Fig. 6.18 | Circular flow of concrete

6.5.2 Changing process of circular construction

However, the proportion of using circular materials in buildings or public spaces is changing.

Currently, limited by technology, waste utilization is low, and the strength of recycled materials is limited. Most of the recycled brick, brick block, concrete cannot bear a lot of weight; therefore, they cannot be widely used in buildings. For the public space, the demand for material strength is much lower than for buildings, and these recycled materials can be used in public space regeneration in recent years.

In the future, with the development of circular technology, waste utilization will be the proportion of usage in public space will go relatively low to 10%, as shown in Fig.6.19.

This research focuses on the first period of circular construction when the use of circular materials in public space regeneration is high.

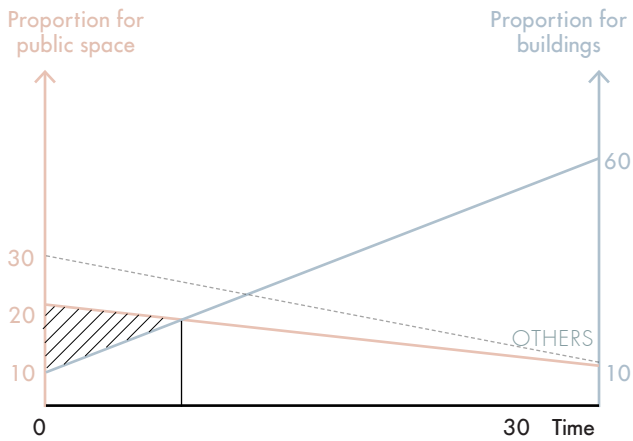


Fig. 6.19 | Proportion change diagram

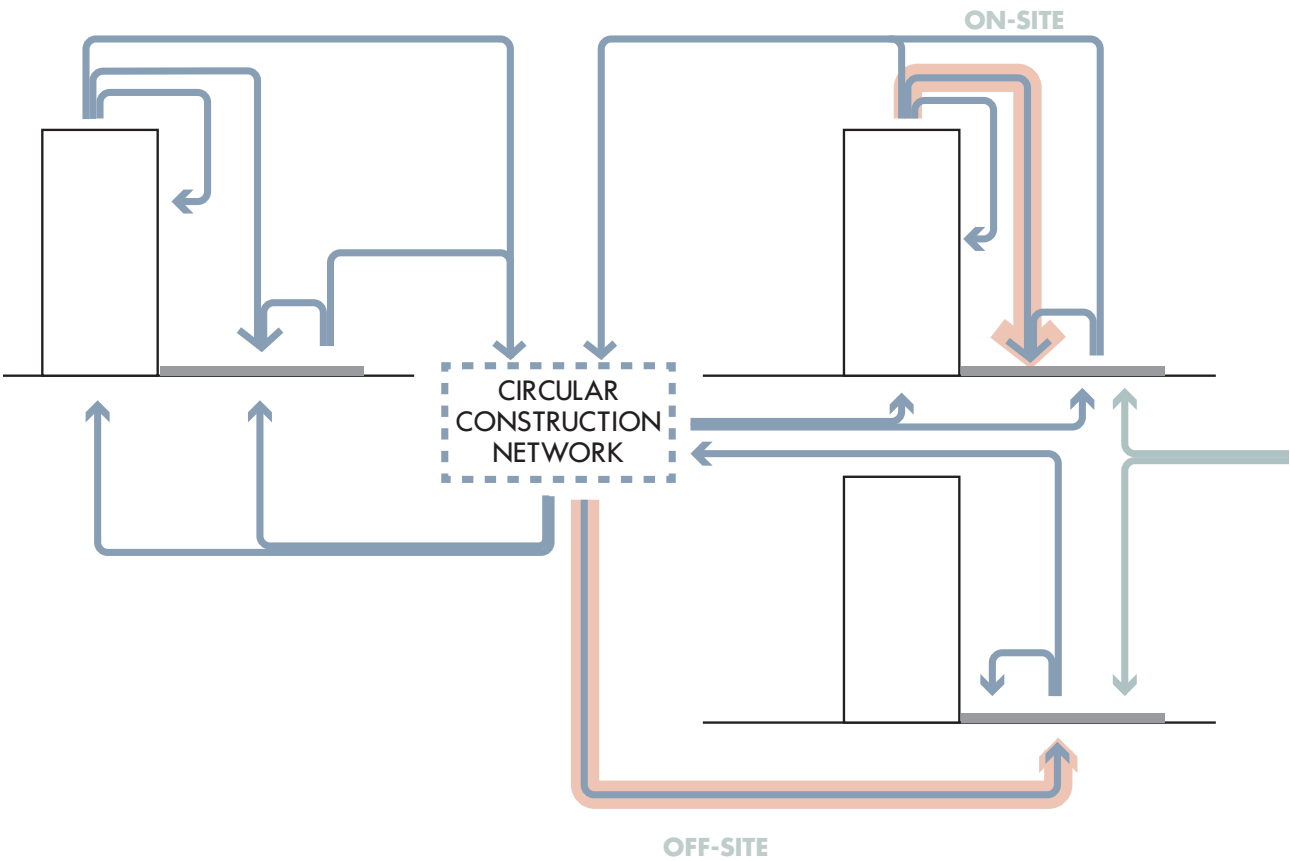


Fig. 6.20 | Circular material flow

6.5.3 On-site & Off-site

Fig. 6.20 shows the whole flows of circular materials from demolition, refurbishment, and maintain sites back to the buildings and public spaces. The various flows in the picture above can also be summarized into two types. One is directly used in the original site, and the other one is used in each site after the treatment of a circular construction network.

The on-site circular regeneration process means the materials from original buildings and public spaces directly reused or recycled on the same site. Some small modules, such as bricks, can be more easily to be reused and recycled on-site. The other materials that need remanufacturing to be recycled cannot finish the process on-site, as shown in Fig.6.21(1).

The off-site circular regeneration process relies on the circular construction network. When the materials flow into the circular construction network, it does not matter if it is recycled in the same site or not, and the processes are both called off-site circular regeneration. Except for the small modules recycled, other kinds of materials and bio-based materials flow in this way, as shown in Fig.6.21(2).

Compared with the off-site mode, the on-site circular regeneration reduced transportation costs, transportation energy consumption, reprocessing costs and reprocessing energy consumption. For the off-site model, sometimes the cost and energy consumption of transportation and handling exceeds the direct use of raw materials, which is not really sustainable. Therefore, the on-site mode, in the long run, is a more sustainable circular regeneration method.

However, the current situation of new workers' estates cannot achieve a large proportion of on-site regeneration due to the material limitation. The cast-in-place construction methods make many materials to be mixed together, and it is hard to separate them, let alone reuse them.

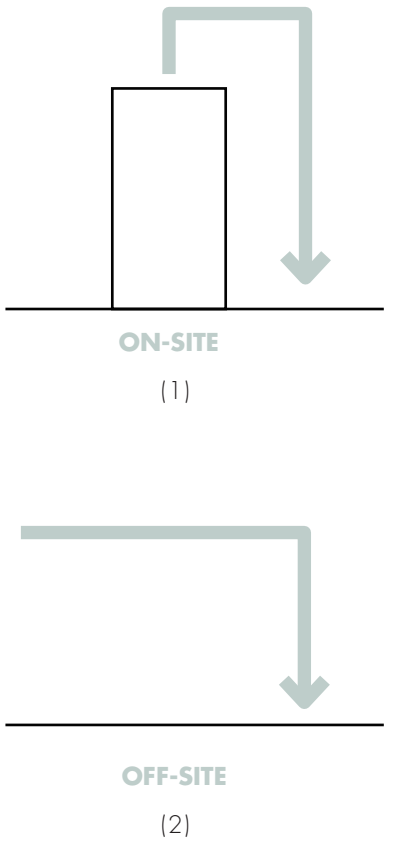


Fig. 6.21 | On-site and off-site

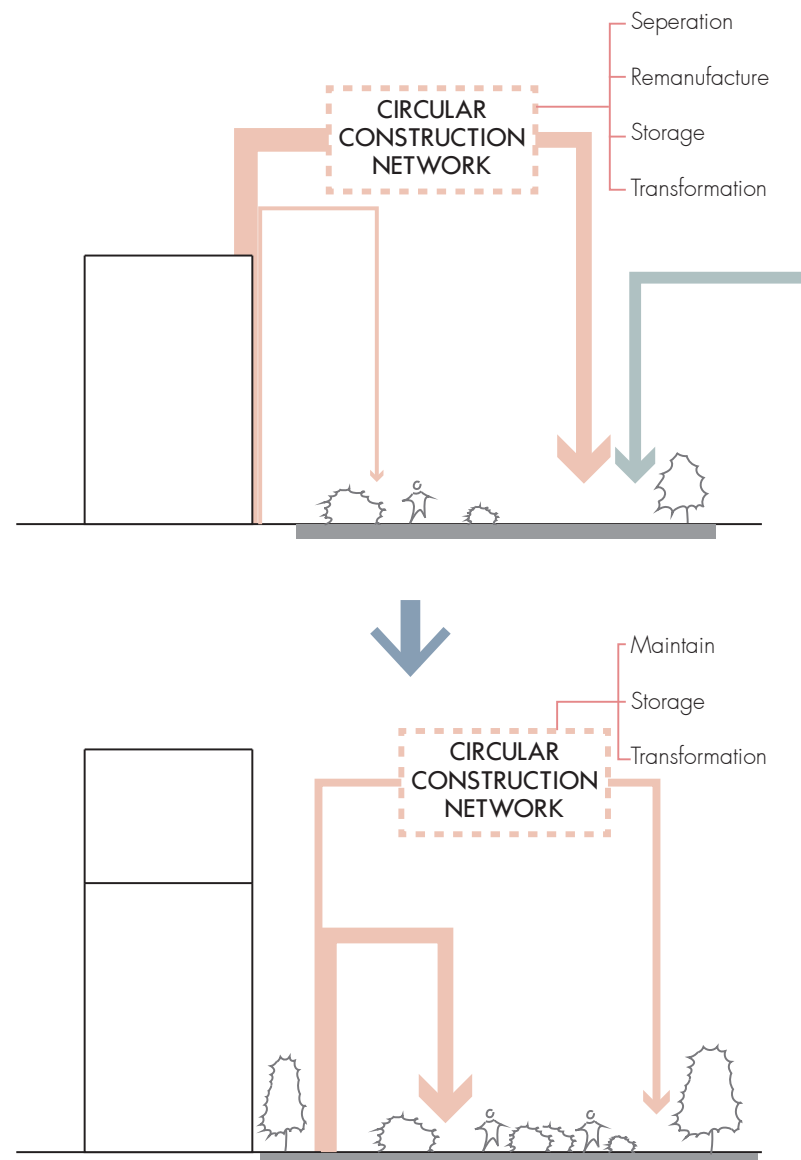


Fig. 6.22 | Conclusion of circular regeneration

6.5.4 Conclusion

Therefore, in the current stage of the regeneration process, there are more circular materials that can be used for public space regeneration. Although a small number of them can be reused on-site, most of them need to be recycled through the circular construction network. However, in the process of regeneration design, minimize the construction of cast-in-place, use prefabricated modules that are easy to be reused in the future, and increase the use of easily recycled bio-based materials.

In this way, after the development of future technology, more circular materials are applied to buildings. In contrast, most of the materials in public spaces can be conveniently on-site circular reused for future regeneration, and only a small part of the damaged materials enter the circular construction network for repair. They will thereby achieve a more sustainable circular regeneration, as shown in Fig.6.22.

6.6 CONCLUSION

- Waste materials from buildings

- Waste materials from buildings mainly includes brick, concrete, metal, wood, plastic and others. They can be classified into three categories: aggregate, components, and modules.
- The circular use of them includes reduce, reuse, and recycle. The aggregates can be reused and recycled. The components and modules are always reused.

- Waste materials used in public space

- Due to the strength limitation of secondary materials and users' motivation of using circular materials, currently, the waste materials are more suitable to be used in public space.
- The materials can be used for regeneration of paved surfaces, landscape, planting, water, structure, furniture, facade, and public buildings.
- 7-12% of the waste brick from building and public space can be reused on-site or recycled off-site to the regeneration of open space.
- 2-7% of the waste concrete from building and public space can be reused on-site or recycled off-site to the regeneration of public space

- Future tendency

- Priority on on-site reuse than off-site recycling.
- The proportion of using circular materials in buildings or public spaces will change. It is the best time to apply these materials to public spaces now. Currently, the circular materials cannot be widely used for building regeneration because of technical limitation. In the future, with the development of circular technology, the circular rate of materials in buildings increases and the proportion of usage in public space will go relatively low.

- Vision for circular construction

- For the current regeneration, take advantage of the largest amount of waste materials that can be used in public spaces. But during the design and construction, try the best to make it more easily for future regeneration. So that, even if there will be less materials from buildings that can be reused in public space, the materials of current public space can be easily reused to cover the future regeneration demand.

7

VISION&PRINCIPLE&STRATEGIES



Fig. 7.1 | Vision Collage

7.1 VISION

Apply the circular construction network to help make circular use of CDDW generated during regeneration of new workers' estate for the improvement of elderly-friendly public space quality to make the public space more sustainable and adaptive to future changes.

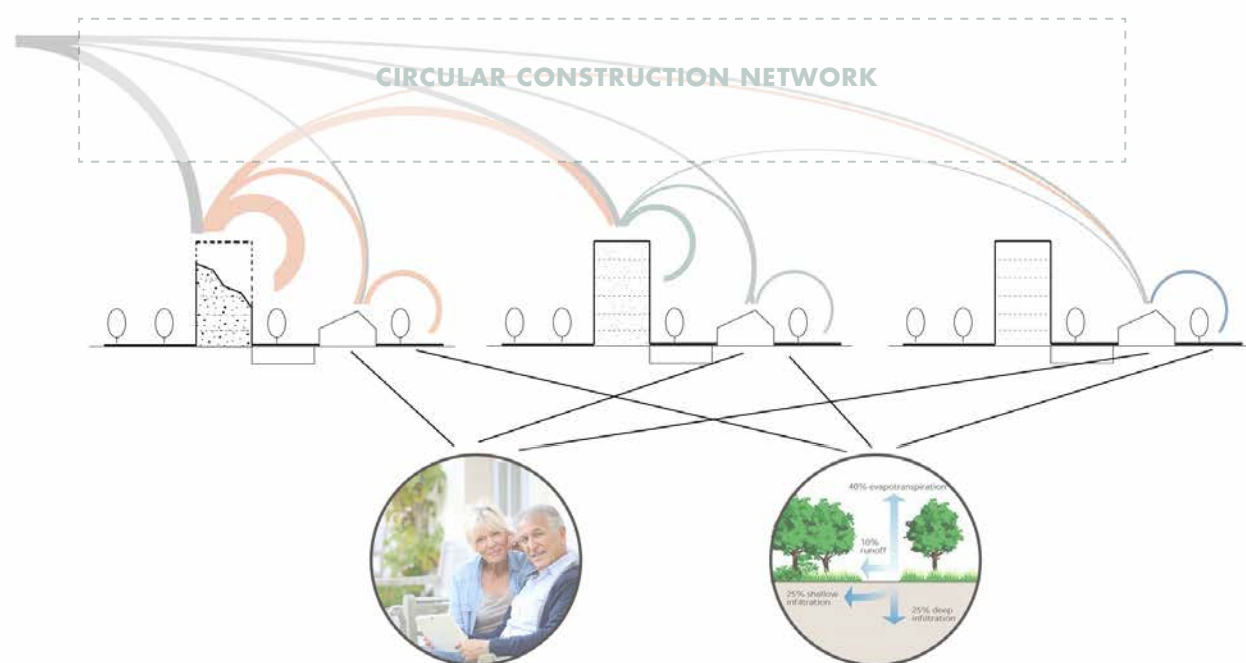


Fig. 7.2 | Vision

7.2 PRINCIPLE

CIRCULARITY	ELDERLY ADAPTIVE	FUTURE ADAPTIVE
- Reduce current material consumption of regeneration - Priority on-site reuse - Reduce future recycle demand - Collaborative circular construction network	- Comfortable - Safe - Diversity - Participateable	- Flexibility - Permeability - Ecology

Fig. 7.3 | Principles

7.2.1 Circularity

The principles are divided into three parts according to the problems and research, as shown in Fig. 7.3.

The main aim of the research is to find how to make circular use of waste building materials. According to the vision, the CDDW will be used in public space regeneration, so the first part of the principle is circularity related to circular construction. According to the three R's, the first step to make a circular and sustainable construction is to reduce material consumption and waste output. Therefore, the current new workers' estates are divided into three types according to their quality, and different strategies are adopted for different classes to minimize the amount of demolition and construction. Destruction of the area that has to be demolished. For estates with only partial regeneration needs (Refurbishment), renew the parts that need to be regenerated, and only carry out micro-regeneration of spaces for estates without the need for building renovation.

Compared to materials that can only be recycled through Circular Construction Network, there are currently some materials that can be directly reused on-site, and on-site reuse should be given priority. This reduces energy consumption and environmental pollution caused by transportation and processing.

In addition to considering the circular use of CDDW for the current regeneration process, the updated public space should be easier to apply circular construction in future regeneration, so that the design is truly sustainable in the long run. Therefore, the recycling demand in future regeneration should be reduced, so that more materials can be reused more directly.

For materials that cannot be reused on-site based on current technology, recycle through a collaborative circular construction network to improve the efficiency of recycling and reduce waste, energy consumption, and pollution.

7.2.2 Elderly adaptive

According to the extremely severe elderly problem in the new workers' estates, to make the public space more elderly adaptive is an important principle.

In order to increase the vitality of community public space, space should be comfortable enough for the activities of the elderly.

The behavior and response reaction of the elderly is lower than that of the young, and their ability to resist danger is low. Therefore, it should be paid more attention to safety in the design.

Although the proportion of elderly people in this type of community is higher than in other communities, it does not mean that the designed spaces only serve the elderly. The new workers' estate is still a mixed community, so space needs diversity. At the same time, different types of activities also need to correspond to a variety of spatial scales and forms. Diverse people and diverse events can make public spaces more

dynamic.
 After retirement, the elderly spend most of their lives in the community. Compared with young people, they spend longer in public spaces, so pay more attention to the participating of spaces in the design of public spaces. Improve the interaction between the elderly and space, functionally fit their living habits, and enhance their interest in using the areas.

7.2.3 Future adaptive

Future adaptive means that the design should be adaptive to future changes that consist of both functional changes and climate change.

Space will be dilapidated, and people 's needs for space are continually changing. Therefore, some changes must happen in space after some time. Thus, the flexibility of the space should be considered in the design to make it easier for it to adapt to future changes. This also helps to reduce the material consumption and garbage generation caused by the renewal.

Climate change is a global problem. Under this premise, the design needs to have good flexibility in adapting to environmental changes and responding to natural disasters caused by rain. The water treatment method based on the permeable principle makes the design adaptive and more sustainable.

From an ecological point of view, the natural environment should be protected to the maximum, all the natural landscapes should be used reasonably, and development and construction activities should always be kept within the carrying capacity of the environment.

7.3 STRATEGY

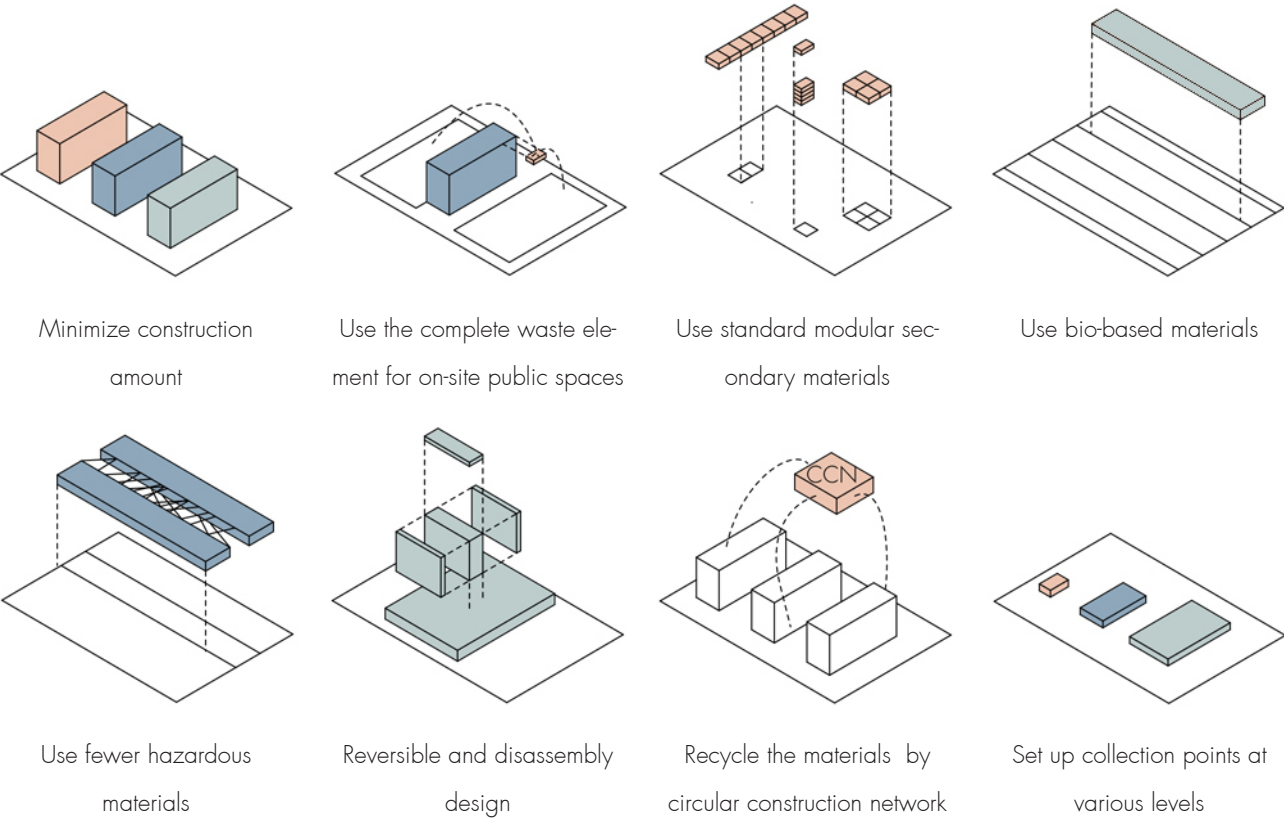


Fig. 7.4 | Strategy of Circular Construction

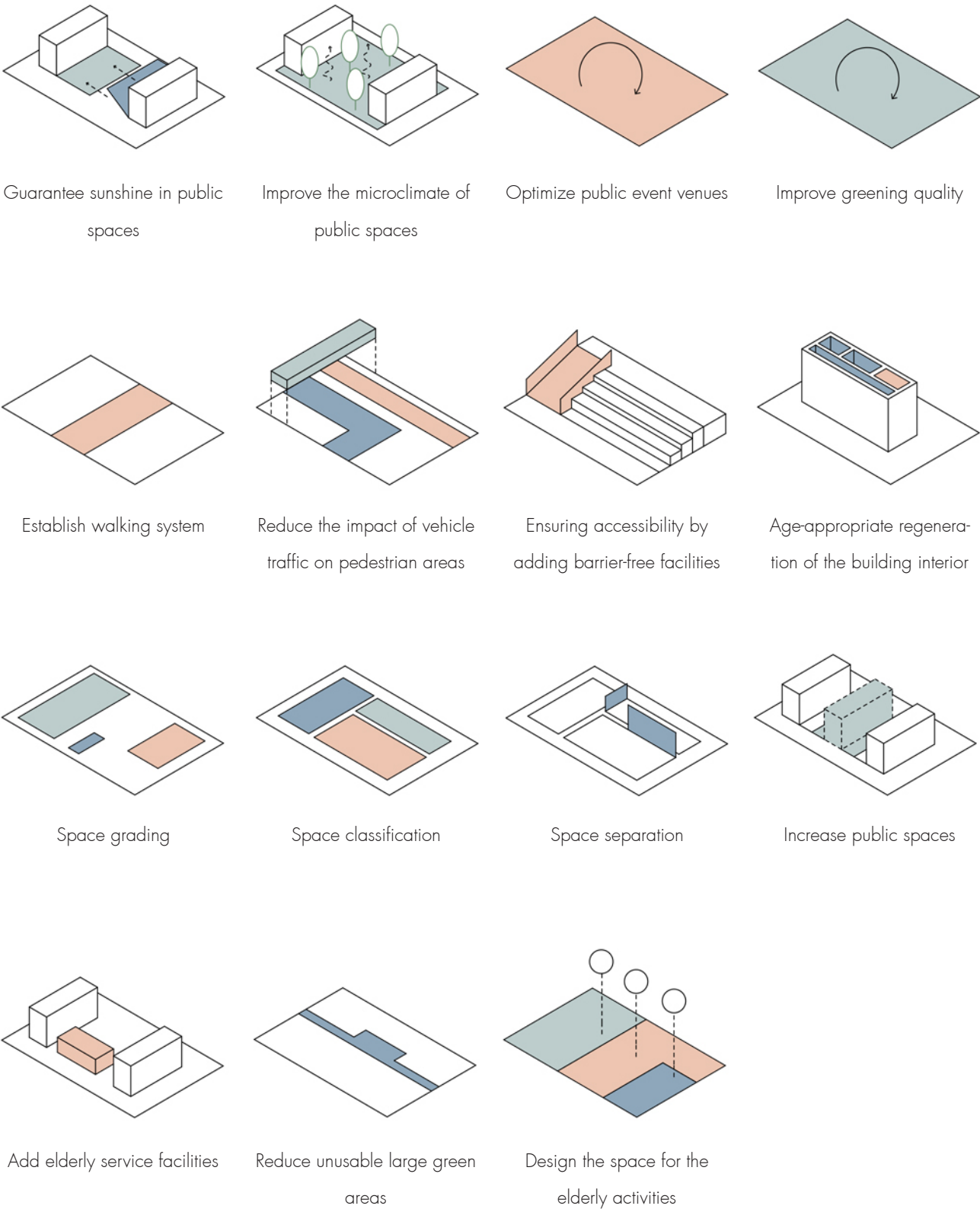


Fig. 7.5 | Strategy of Elderly Adaptivity

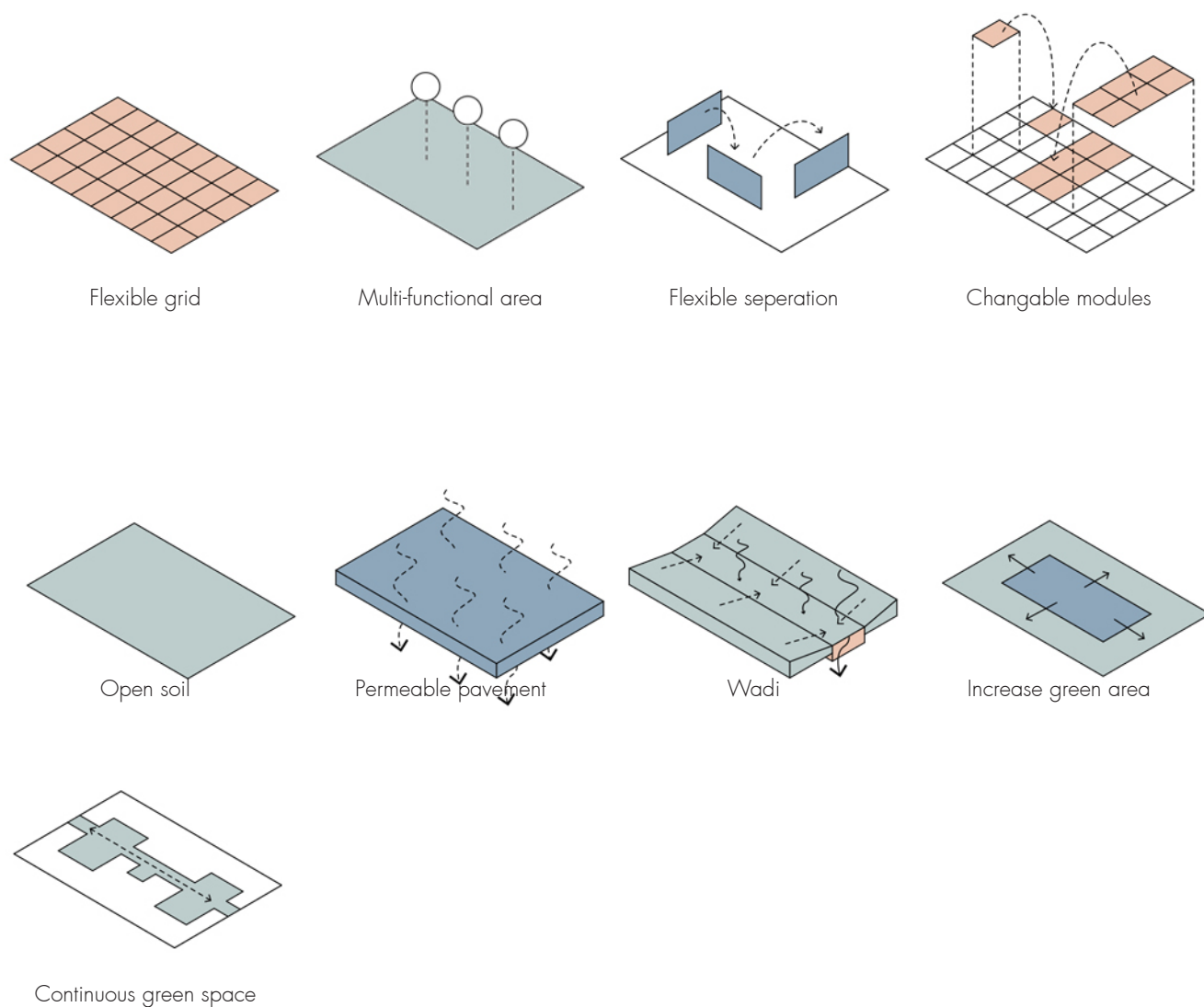


Fig. 7.6 | Strategy of Future Adaptivity

7.3.1 Strategy of circular construction

- Divide new workers' estate into three categories (demolition, refurbishment, and maintain) and use different regeneration strategies to minimize the construction amount.
- Try to remove the bricks completely from the building and use them in the original site first.
- For places where secondary materials must be used, standard modular secondary materials are used, which are convenient for future dismantling and make future reuse easier.
- Use bio-based materials to reduce environmental impact and emission. Bio-based products can also be easier to reuse.
- During the reuse, recycle and construction process, reduce the use of hazardous materials like asbestos and adhesive. This can both decrease the environmental impact and make future reuse easier.
- Use reversible and disassembly design so that different layers of products can be dismantled from each other easily for reuse.
- For the materials that cannot be reused directly currently, apply the circular construction network to form an efficient material flow platform to recycle the materials.
- Set up collection points at various levels to collect and separate the waste materials hierarchically.

7.3.2 Strategy of elderly adaptivity

- To make the public space comfortable to use, and meet the needs of the elderly in the sun, guarantee there is enough sunshine in the open space.
- More green areas are needed to improve the microclimate of public space. The public space should also help relieve the inner heat issue.
- The quality of public event venues like square and shelters need improvement.
- The quality of the green area needs improvement from plant coverage, plant species diversity, and aesthetics.
- Establish a walking system that can have alternative access to every public space.
- To guarantee the safety of the elderly and also to improve the walking experience in the public space, try to separate the walking area from vehicle roads to form a walking free zone. Use the structure of the building itself to build a sky corridor to cross the street.
- Since some older people cannot walk, ensure accessibility by adding barrier-free facilities.
- Age-appropriate transformation of the building interior, such as the addition of elevators, and in the living places for elderly families, make particular renovations to furniture configuration and details protection, to benefit the elderly daily life.
- Grade public spaces that undertake public activities of varying degrees of crowd concentration into public space, semi-public space, and semi-private space.
- The events of the elderly mentioned in Chapter 5 are classified, as shown in Table 7.1, and are divided into four categories. Dispersed means people use the area alone or in small groups. Gathering means a large group of people share the space together. Also, classify the public space for different types of functions.
- To avoid the influences between different groups of people and form a space suitable for human activity scale, construct some (not in all cases) separation to separate the area.
- In places where the public space environment is too harsh, buildings can be demolished to increase public space and improve the quality of public life.
- Add elderly service facilities such as elderly activity centers, daycare centers, nursing homes, elderly schools, elderly canteen, community hospitals, and small markets.
- To increase the vitality of public space, reduce unusable large green areas so that people can use every public space.
- Corresponding to various activities in Table 7.1, design the space for the elderly activities.

	GATHERING	DISPERSED
PASSING	A2 F1	A1 A2 B2 D1 F1 F2
STAY	A1 A2 B1 C2 D1 E1 E2	A1 A3 B1 C1 C2 C3 D1 D2

Table. 7.1 | Classification of elderly activities

- A Leisure**
 - A1 Entertainment
 - A2 Exercise
 - A3 Reading/ Listening
- B Social**
 - B1 Chat
 - B2 Greet
- C Remain**
 - C1 Rest
 - C2 Observe
 - C3 Wait
- D Housework**
 - D1 Accompany
 - D2 Outdoor housework
- E Deal**
 - E1 Shopping
 - E2 Service
- F Move**
 - F1 Passing
 - F2 Exercise

7.3.3 Strategy of future adaptivity

- To make the public space adaptive for changes, use the flexible grid to divide the public areas, which offers maximum opportunity for alternatives with a flexible framework.
- Design multi-functional areas to hold various kinds of activities. People can flexibly use public spaces according to their needs, and such spaces can better adapt to changes in people's needs and preferences.
- The separation mentioned before should also be alternative, which can change the layout as needed easily.
- According to the size of the grid, design standardized modules that can be matched with them, and these modules can be flexibly placed in different positions in the grid.
- For permeability, increase the area of open soil to infiltrate precipitation most naturally.
- For places where hard paving is required, use permeable materials.
- Use the method of Wadi to collect, buffer, and penetrate the rainwater, which is sustainable for water management.
- From the perspective of ecology, increase the natural green area to protect the ecosystem.
- Connect scattered green spaces with green belts to form continuous green spaces to protect ecological health and biodiversity.

7.4 TOOLBOX OF MODULES

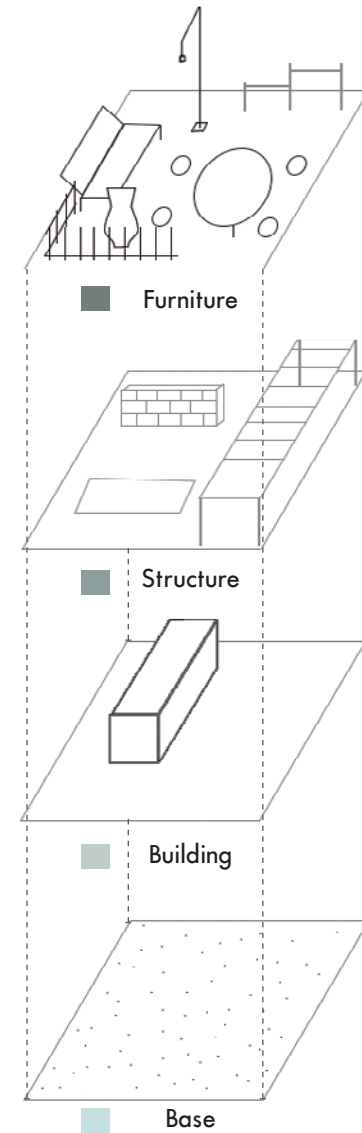
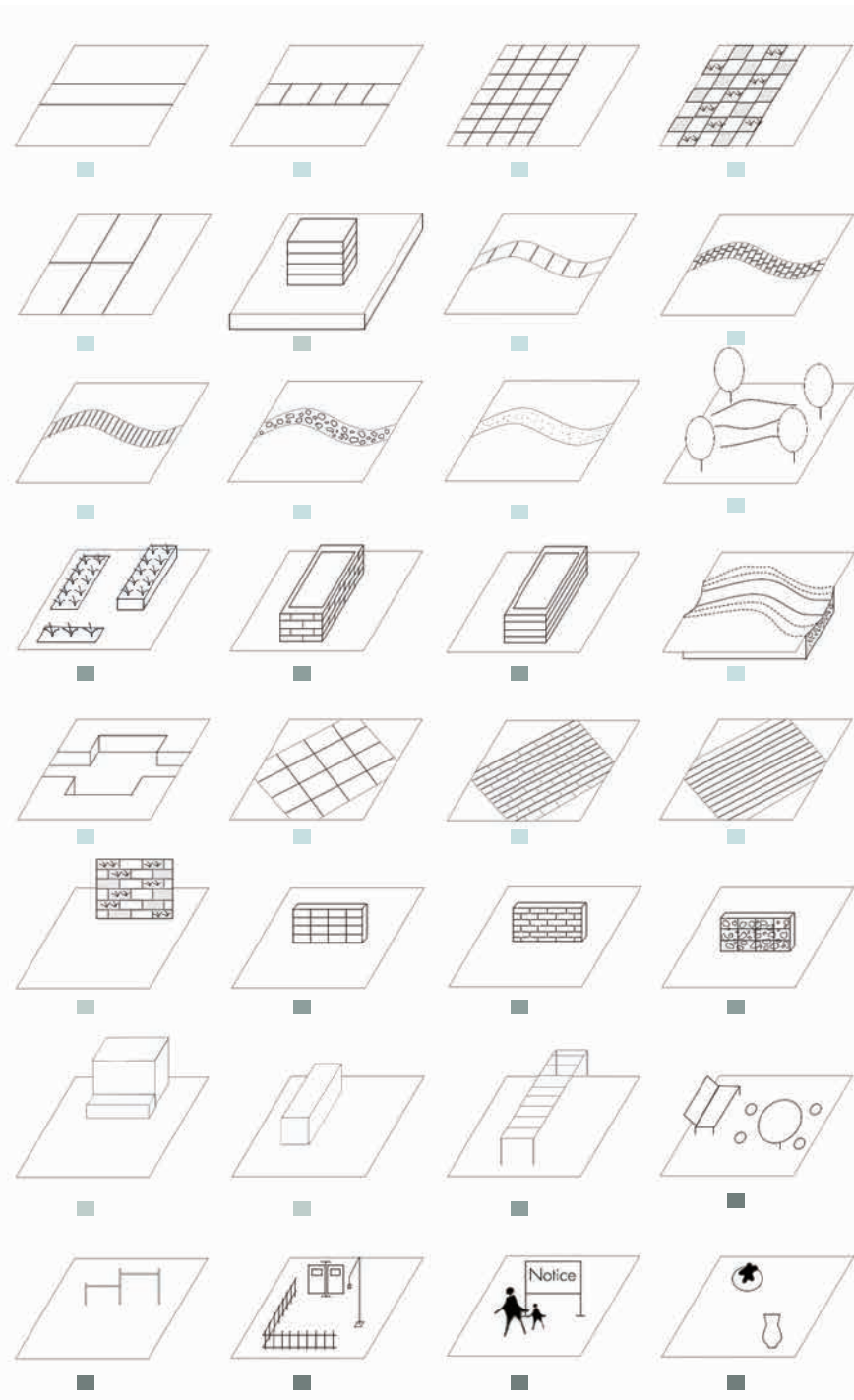


Fig. 7.7 | Toolbox of different layers of public space products

Fig. 7.8 | Combination of the layers

7.4.1 Combination of layers

The combination of various products in the toolbox (Fig. 7.7) forms an entire public space (Fig. 7.8). These products are divided into four categories, base, building, structure, and furniture.

The regeneration of road, parking, path, landscape, planting, water, and square belongs to base. They mainly consume concrete, brick, asphalt, bio-based materials. The base is the necessary component of each public space and consumes the most materials.

The building layer contains the facade regeneration, use the roof, and build new community hubs for circularity activities. The structure layer means the new structures added to the

public space, which can reuse the waste brick, metal and use more bio-based materials to form partition, gallery, and shelters to improve the quality of open space.

The furniture layer contains furniture for stay, for activities, for display, some functional furniture such as garbage bins, lights, fences, and decorative furniture. The composition of these products are complex, and most of them are used directly after being produced by the factory, the proportion of recycled building materials is small.

All the materials consumed in the public space are summed up by these four layers.

7.4.2 Elderly activities and modules

A1 Entertainment

Space for entertainment activities such as chess, cards, music and leisures.

A2 Exercise

Space for exercises such as dance, Taichi with fitness equipments.

A3 Reading/ Listening

Space for static activities, the surrounding environment should be quiet, providing shelter.

B Social

Space for meeting and communication with others.

C Remain

Space for rest (important for the elderly), observe and wait.

D1 Accompany

Activities of the elderly accompanying the pets or the grandchildren.

D2 Outdoor housework

Space for outdoor housework activities such as drying and planting.

F Move

Space as path and walking free zones for passing and exercises.

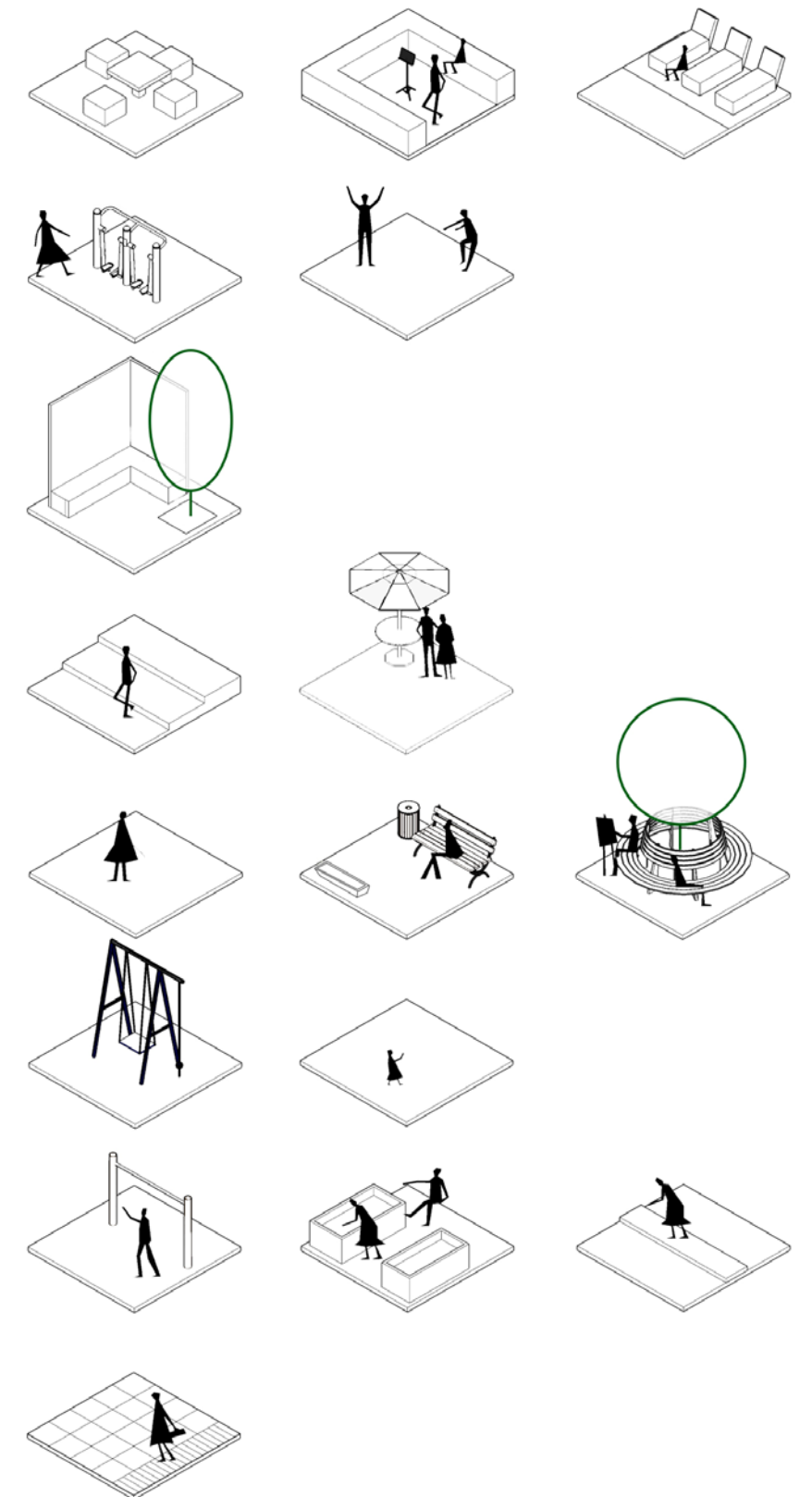


Fig. 7.9 | Modules for elderly activities

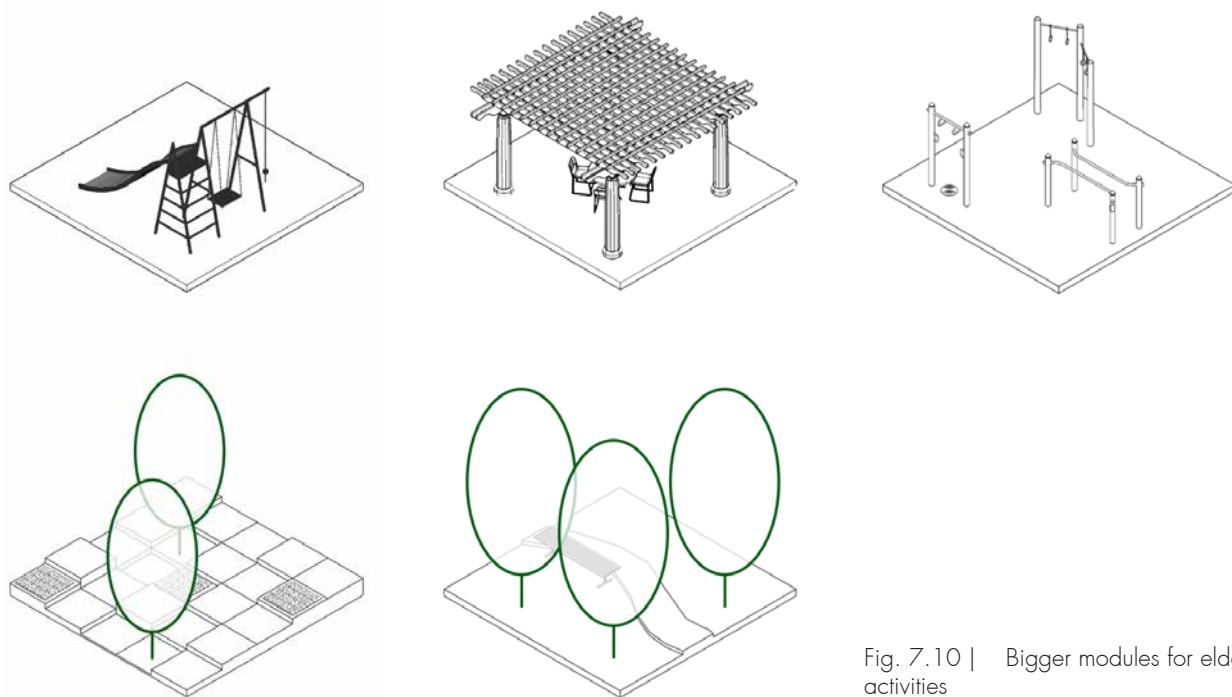


Fig. 7.10 | Bigger modules for elderly activities

According to the activities of the elderly, the layers in the toolbox are combined to form a public space module that meets the characteristics of them.

Fig. 7.9 are some examples of modules designed for various activities. In the application process, more modules can be formed through other combinations. Modules suitable for a specific event generally include the ratio of open soil and hard pavement in the module, the materials used, whether the structure needs to be enclosed or sheltered, and the furniture suitable for these activities. These modules provide high-quality venues for the corresponding events, increase attractiveness, and enhance the vitality of the space.

The module corresponds to the different hierarchy of public spaces with different sizes. As shown in Fig.7.10, it shows examples of modules that can be placed in a more open area and undertake more people to carry out activities.

7.4.3 Circularity of the modules

Because these modules are composed of various layers in Figure 7.7, and as introduced in Chapter 6.3, these layers are all products made of secondary materials, so these modules entirely follow the principle of circularity.

The circular material used in the base layer can be prefabricated standardized concrete slabs, cement slabs, or bricks, as shown in Figure 7.11-1, reducing the use of secondary materials in the in-situ construction method. Taking a 3m * 3m module as an example, a combination of 25 secondary concrete slabs of 0.6m * 0.6m can be used as the base. Concrete slabs of this size have moderate weight and size, which is convenient for transportation. The separation in these modules can be preferentially constructed using the complete bricks removed from the building, as shown in Figure 7.11-2. Bio-based materials can also be used.

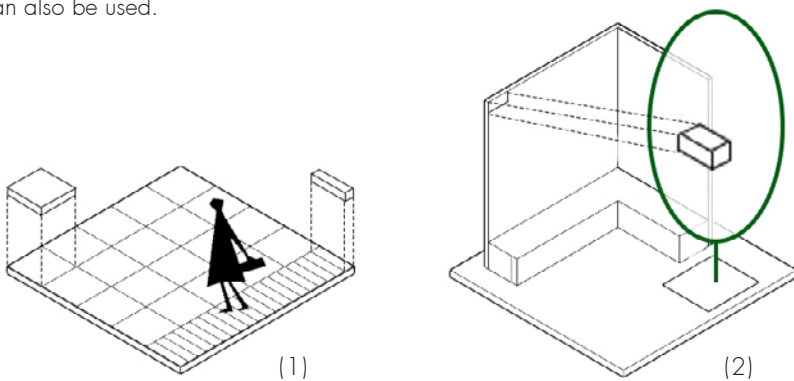


Fig. 7.11 | Circularity of the module

Reversible

In order to make the design easier to be reused in the future changes, to reduce future recycle demand, reversible and disassemble design is used, as shown in Fig. 7.12.

Reduce the use of permanent materials such as cement as binders. A variety of products are combined using removable parts such as screws. The nut on the screw serves as a connection joint to fix the furniture on the upper layer more flexibly. This kind of lego-like construction makes the module easy to disassemble so that the removed product can be easily applied to other modules.

7.4.4 Adaptivity of the modules

Multifunctional

Among all the modules, some modules undertake specific functions, as shown in Fig. 7.13-1. In the design process, the functions assumed by the space are considered, and corresponding furniture or other auxiliary structures are set. Besides, some modules do not undertake specific functions, making it versatile by design, as shown in Fig. 7.13-2. Do not put too many restrictive products in it during design, but the users are free to decide how to use the space. By setting up the multi-functional module, the adaptability of the modules to future functional changes is improved.

Permeable

The base of modules can be divided into open soil and hard pavement. The open soil modules are water permeable, can infiltrate, filter, and collect rainwater. Use Wadi water treatment techniques in these modules to manage the water flow direction, and guide the water collection and use.

For those hard-paved modules, the applied base layer material should be water permeable.

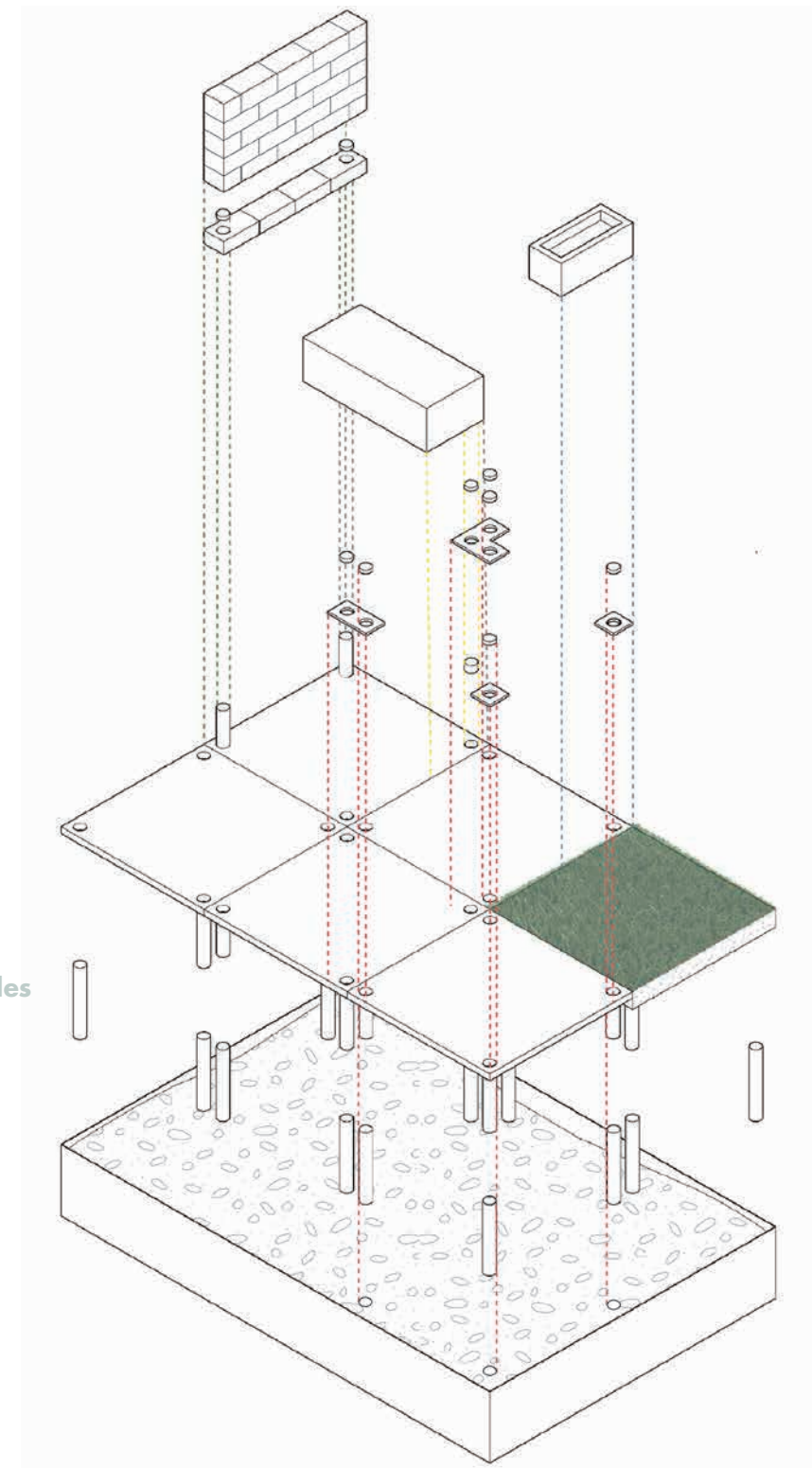


Fig. 7.12 | Reversible combination

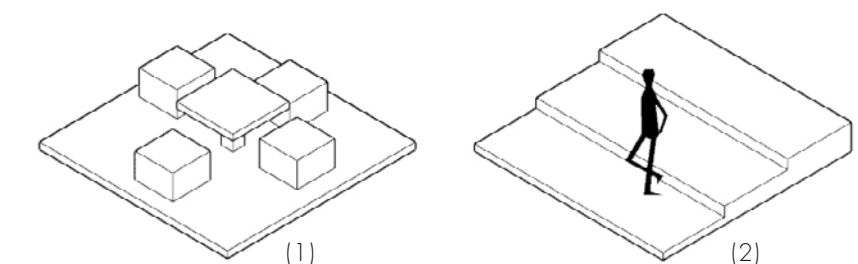


Fig. 7.13 | Flexibility of the module

7.4.5 Multi-grid modules

In the above, the combined form of modules occupying a single grid, elderly-adaptive design, circular construction, and adaptivity are introduced in detail. Because the size of a single grid is only 3m * 3m, it is very restrictive in terms of spatial scale. In order to form a larger space to accommodate more people to carry out activities, a combined module occupying multiple grids is created. The following sections will select two multi-grid cases to analyze circularity, elderly adaptivity, and future adaptivity.

Case1

The first case is a combination of 4 grids with the function of planting, as shown in Fig. 7.14. It can hold different types of farming. The users can plant on the ground or the planting beds. Planting as a cultural and traditional characteristic of Chinese people is an enjoyable activity for the elderly. It is also a dream of many people because when moving to an apartment like this, they are not able to have their own garden. It will be attractive to have a space like this for the residents to plant something.

The materials used in this module include bricks, concrete, and mud. The soil comes from the top layer of the construction mud of the new building's foundation. The base of the square is made of recycled permeable concrete board, following the strategies of using standard modular secondary materials and permeable pavement. The walking path in the middle of the soil for passing uses the recycled bricks. The waste bricks from the building are re-manufactured into ground tiles. The planting beds are built by waste bricks directly, to use the complete waste element for on-site public spaces.

From the future adaptivity perspective, the layout of planting beds is flexible because they use the reversible installation method. It is also water flexible, using the Wadi, see in Fig. 7.16. Wadi is a sand trench or

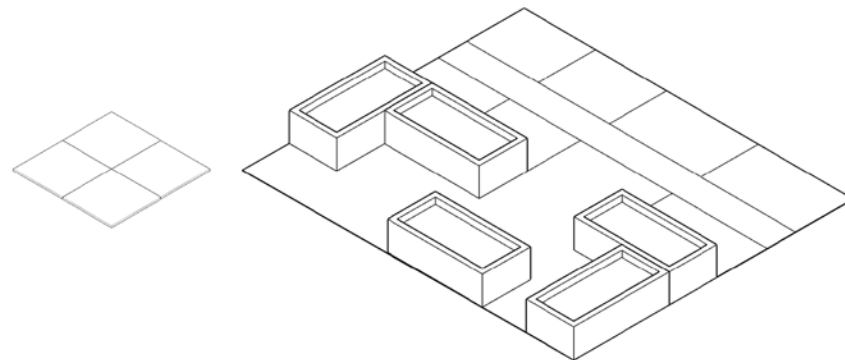


Fig. 7.14 | Four-grid module

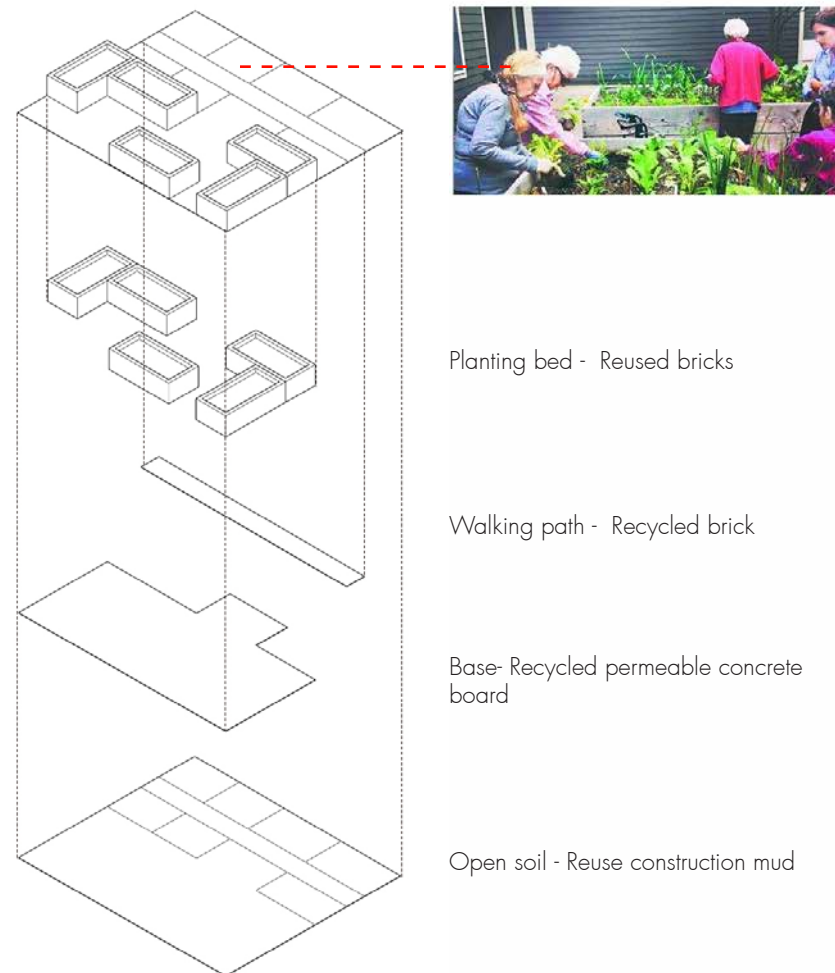


Fig. 7.15 | Circular materials of the module 1

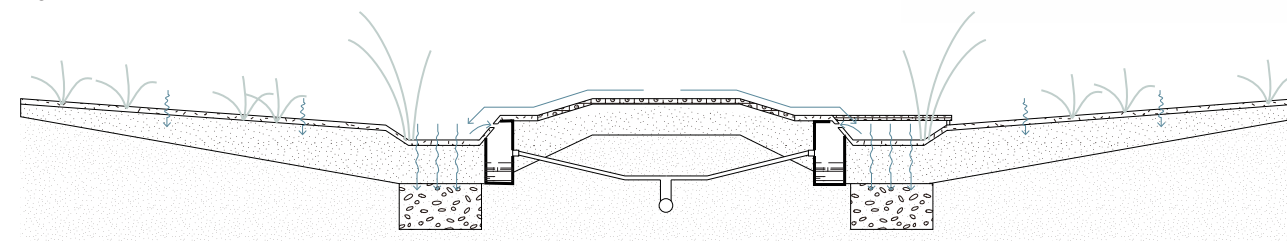


Fig. 7.16 | Water flexibility of the module 1

ditch filled with gravel and sand. The height difference is used to guide the flow of water to this place, and the top layer of the Wadi is planted with permeable soil. Below this level is a suitcase that can be filled with crushed stone, lava stone, or baked clay particles. These materials have a lot of room for rainwater to flow away. To prevent the flooding of Wadi during heavy rains, Wadi can be equipped with sloops. These are overflow facilities connected directly to the drainage pipes. If the water rises above the oral water level, the water will flow through the oral water to the sewer (Amsterdam Rainproof). Meanwhile, the farmland and planting beds help build a new eco-system to help increase biodiversity and maintain ecological health.

Case2

The second case is a combination of 6 grids for the elderly people accompanying children or pets, see in Fig. 7.17. There is a unique activity for the elderly in China. Many grandchildren live with the elderly. The events of the elderly are sometimes together with the children. Therefore, the design of the module should be suitable for children, in the meantime, meeting the demand of the rest of the elderly.

The materials used in this module include bricks, mud, mixed materials, and bio-based materials, as shown in Fig. 7.18. The reuse of construction mud helps create a landscape with a rich height difference. There is an artificial pool which is made of waste bricks. The walking path also uses recycled bricks. Bio-based materials like wood are used for rest platform. There are two sources of furniture materials. One is to reuse furniture directly. The other one is to collect waste wood, plastics, and metals in the building, which will be processed into secondary furniture.

As shown in Fig. 7.19, the height difference in landscape not only provides an interesting experience for users but also helps collect the water as the Wadi. The flooding of Wadi during heavy rains will flow to the artificial pool and be gathered there for later use.

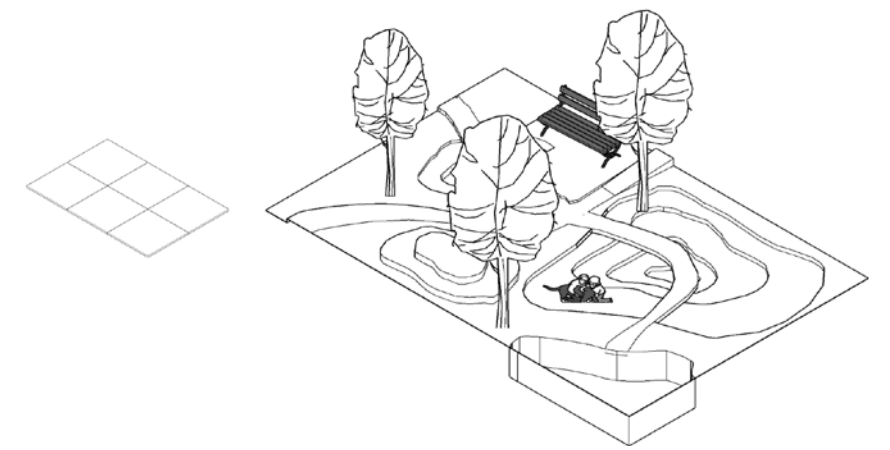


Fig. 7.17 | Six-grid module

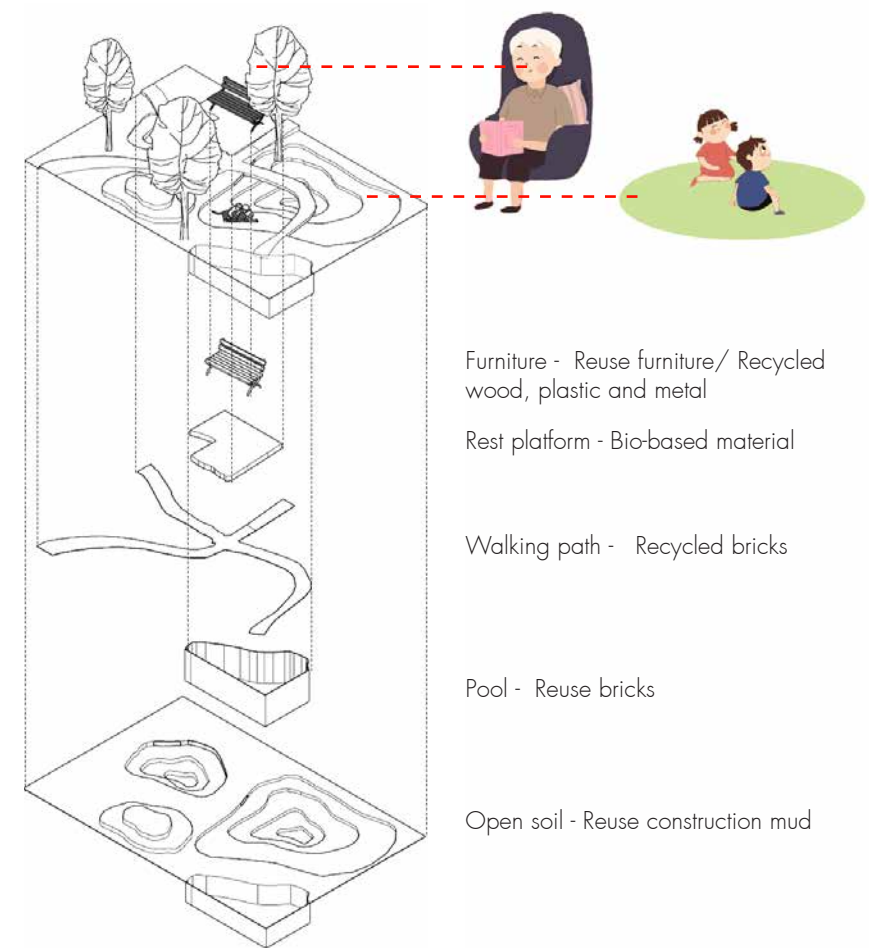


Fig. 7.18 | Circular materials of the module 2

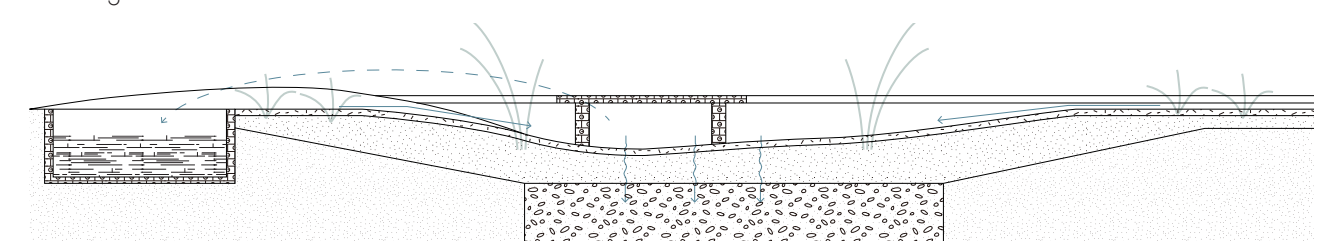
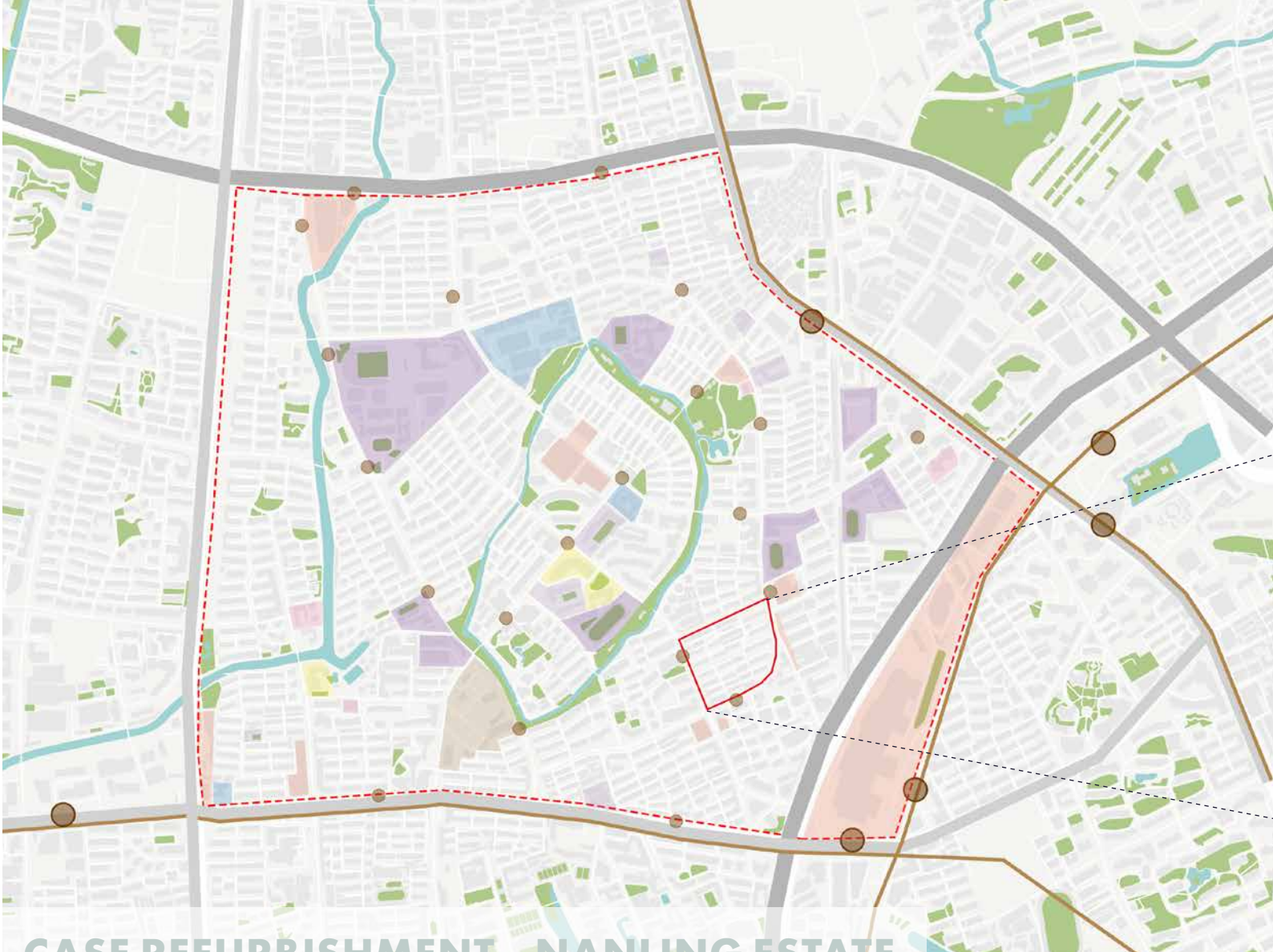


Fig. 7.19 | Water flexibility of the module 2

8

PUBLIC SPACE DESIGN



CASE REFURBISHMENT--NANLING ESTATE

8.1 SITE ANALYSIS

8.1.1 Context analysis

The location of the site has already been introduced in Chapter 4.4. The context zoomed to surrounding the site will be analyzed in this section, as shown in Fig.8.1. The area is limited by two main roads and two secondary roads. The texture of the estates around looks similar to the site's, because most of them are new workers' estates as well. They are new workers' estates built in different years, while some of them have already been regenerated into high-rise new estates.

In the middle of this area, there is a circular green belt surrounding some public function buildings. Together with the green belt is a tributary of a river. The site is near to the green belt, but not well connected to the green area. There are plenty of schools and kindergartens, but the number of nursing homes cannot cover all the areas. The main commercial center is on the east side of the area, which is also near to the site, without continuous connection. The nearest subway station is also on the east side of the area, which means that the walking experience between the site and the commercial center and the green center needs to be improved.

The small shops are mostly located on the east side of the site, so it is better to enhance the business identity on this side by adding more types of commercial and improving walking experience. Through these methods, it will attract more people and increase the vitality of the street. Meanwhile, create a green belt to link the site with the green core. Therefore, the site is the intersection of these two zones.

Fig. 8.1 | Context analysis



Fig. 8.2 | Original master plan

8.1.2 Public space status

The original master plan of the site is shown in Fig.8.2, showing the current building location and public space layout.

Among the 24 residential buildings, the six yellow buildings in the top layer of Fig.8.3 are the buildings with the worst quality. It is because of the other buildings have already been regenerated in recent years. These 6 buildings need to be renewed or rebuilt. The road system is shown in the middle layer of Fig.8.3. It has four entrances connecting to the city branch road. The vehicle roads reach each door of the buildings, and the cars are parked along with them, which occupies a large amount of public space. And people and vehicles share the same area; there is no walking free zone.

The public areas are shown in the bottom layer of Fig.8.3. On the west-north side of the site, the open space is extremely scarce. There is almost no public space except for the car space. At the same time, although there are more public spaces on the east side of the site, the spaces are not graded, and there is no central public space. The use of public spaces is not good either.

The design should start with solving these problems.

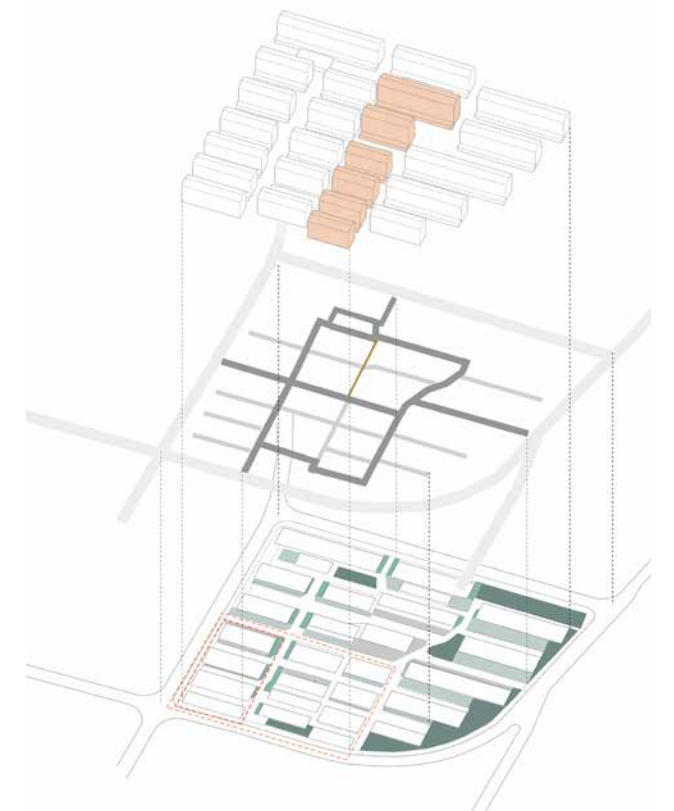


Fig. 8.3 | Problem analysis

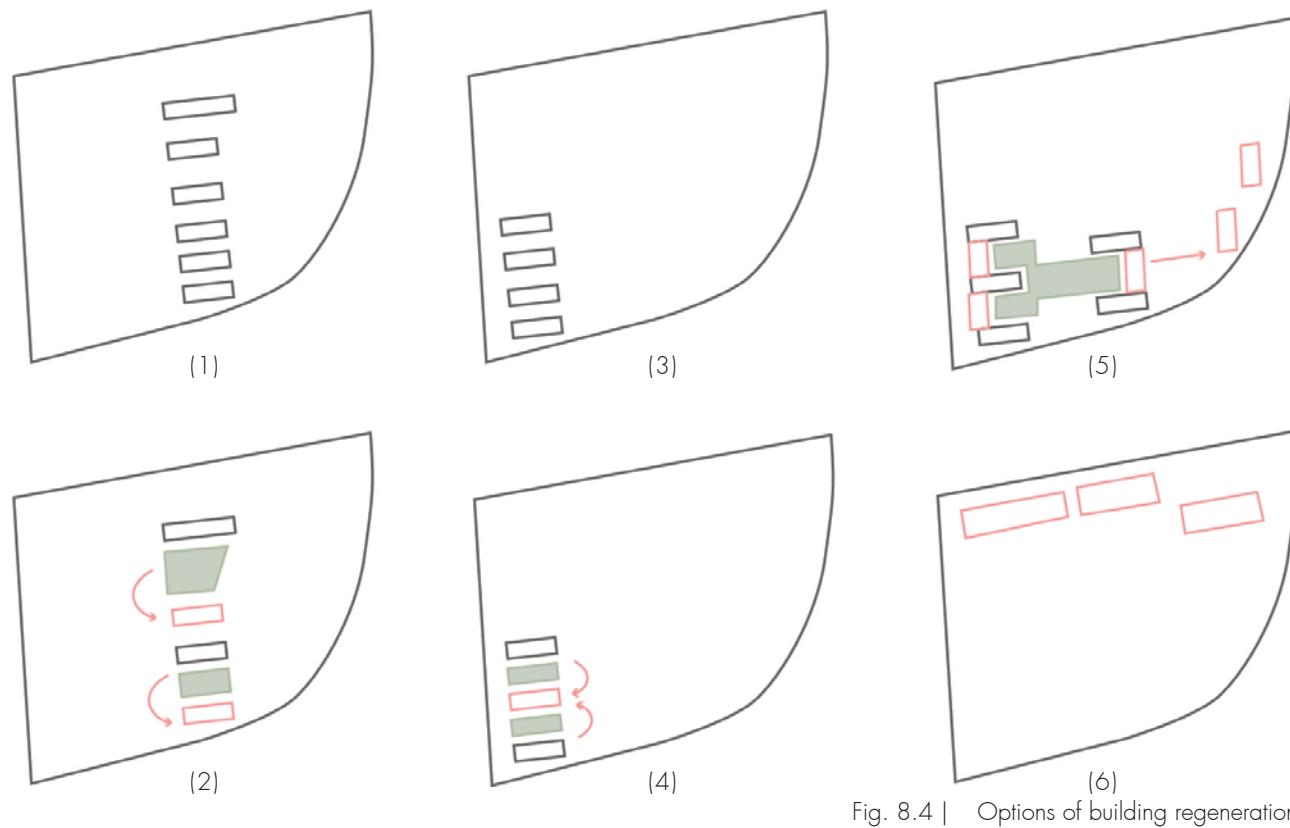


Fig. 8.4 | Options of building regeneration

8.2 GENERAL REGENERATION

8.2.1 Building Regeneration

The six dilapidated buildings are shown in Fig.8.4 (1), to increase public space while minimizing the construction amount, two of them are demolished and add the area to the red buildings in (2). The public space quality in (3) is so low that two of them are demolished and rebuilt into one to increase the open space, see in (4).

To guarantee the sunshine in the public space, the height of the buildings cannot be too high to hold all the demolition area. Therefore, add the area to the side of the buildings, as shown in (5). In order not to destroy the original texture of the estate, place the east-west buildings on the side of the site. As there is a need for adding elderly service facilities, place such functions on the ground floor of these buildings. Since the added area is not balanced with the demolition area, add the extra floors in the back roll of buildings.

As a result, the demolished buildings are as shown in Fig.8.5-1, and the newly built buildings and buildings with extra floors are as shown in Fig.8.5-2. The building with a red outline is the building which will only be refurbished.

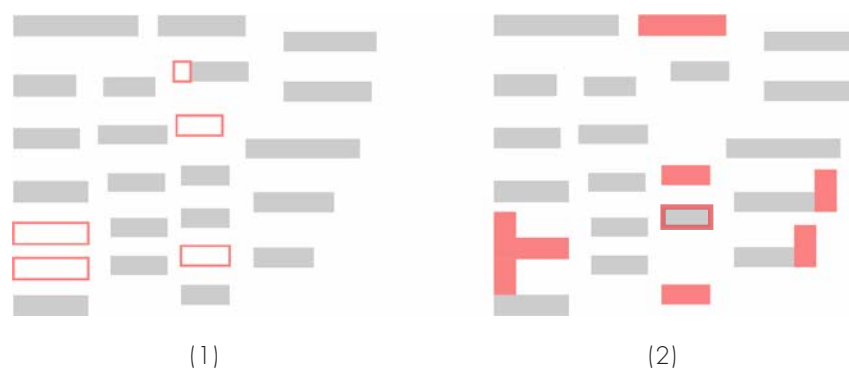
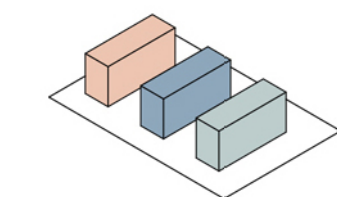
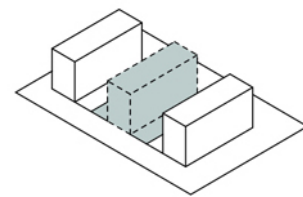


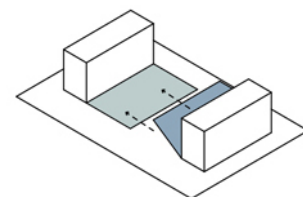
Fig. 8.5 | Decision of building regeneration



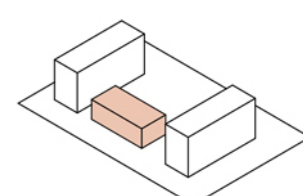
Minimize construction amount



Increase public spaces



Guarantee sunshine in public spaces



Add elderly service facilities

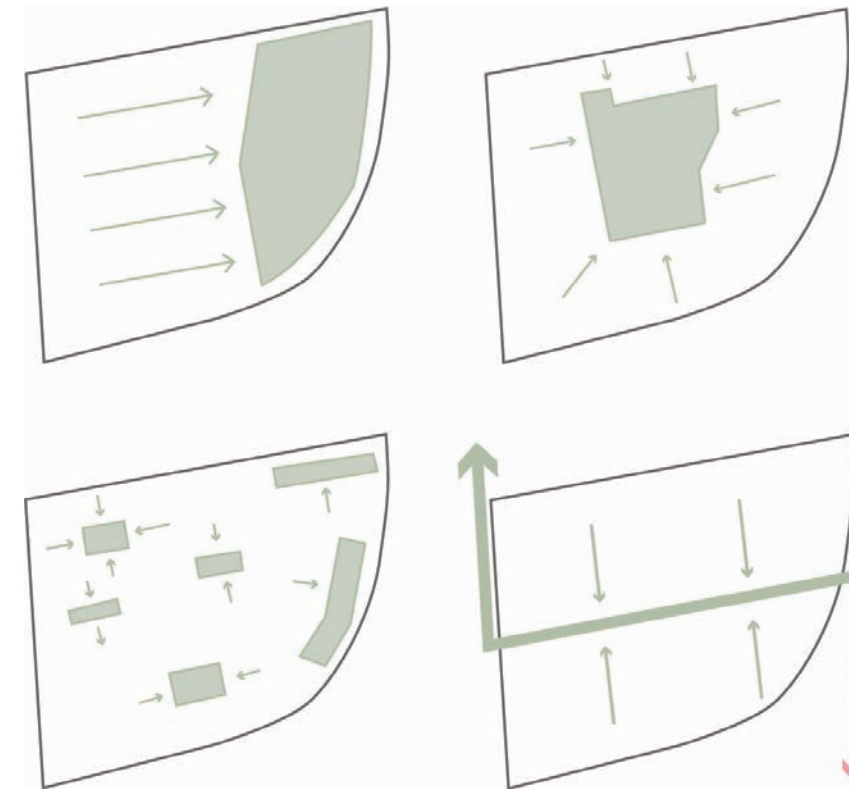


Fig. 8.6 | Options of green structure

8.2.2 Green Structure

There are four plans for the green structure: following the current situation, form a centralized public space, form several dispersed public spaces, and form a green belt in the middle to make a connection, as shown in Fig.8.6. Follow the principle of diversity, according to the strategy of space classification, mix and apply four options to form a three-level public space, see in Fig.8.7.

The public space is the central open area in the community, open to all the people. Because of the middle green belt divided the site into two parts, there is one semi-public space in each area, as public space mainly for residents. The semi-private space is the yard shared by the residents of the surrounding two buildings.

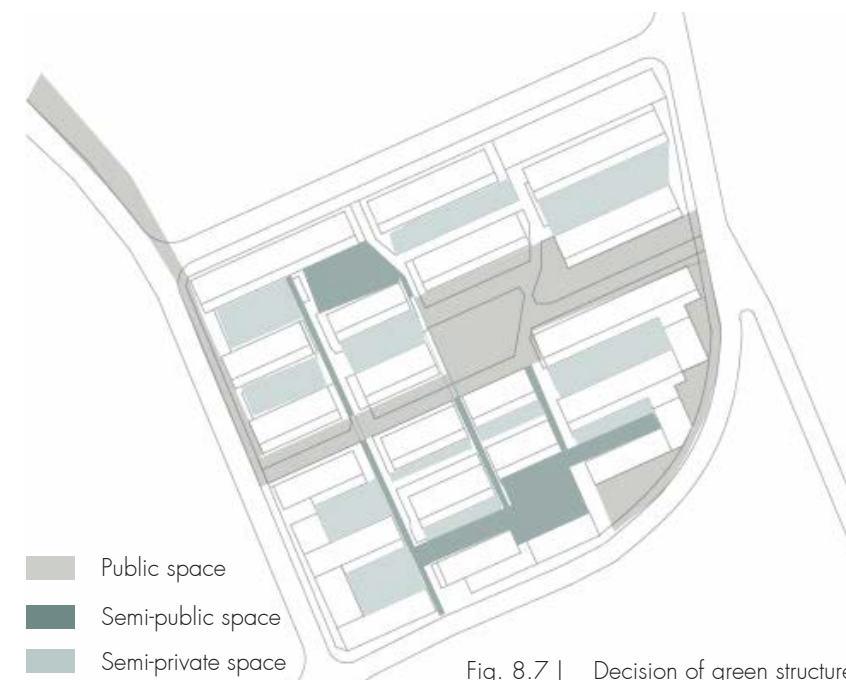
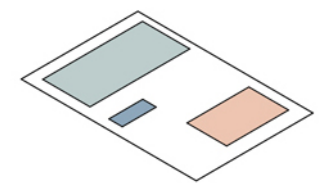
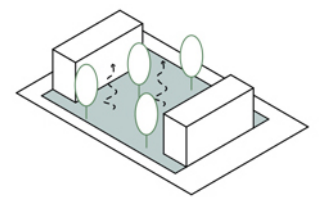


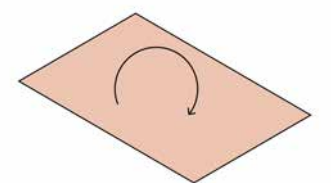
Fig. 8.7 | Decision of green structure



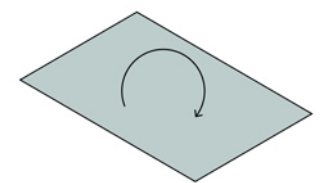
Space grading



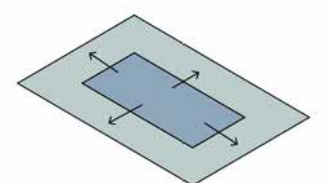
Improve the microclimate



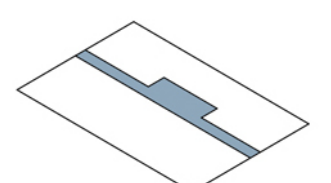
Optimize public event venues



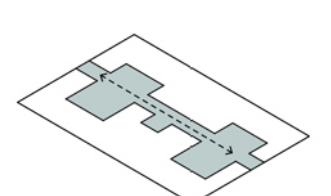
Improve greening quality



Increase public spaces



Reduce unusable large green areas



Continuous green space

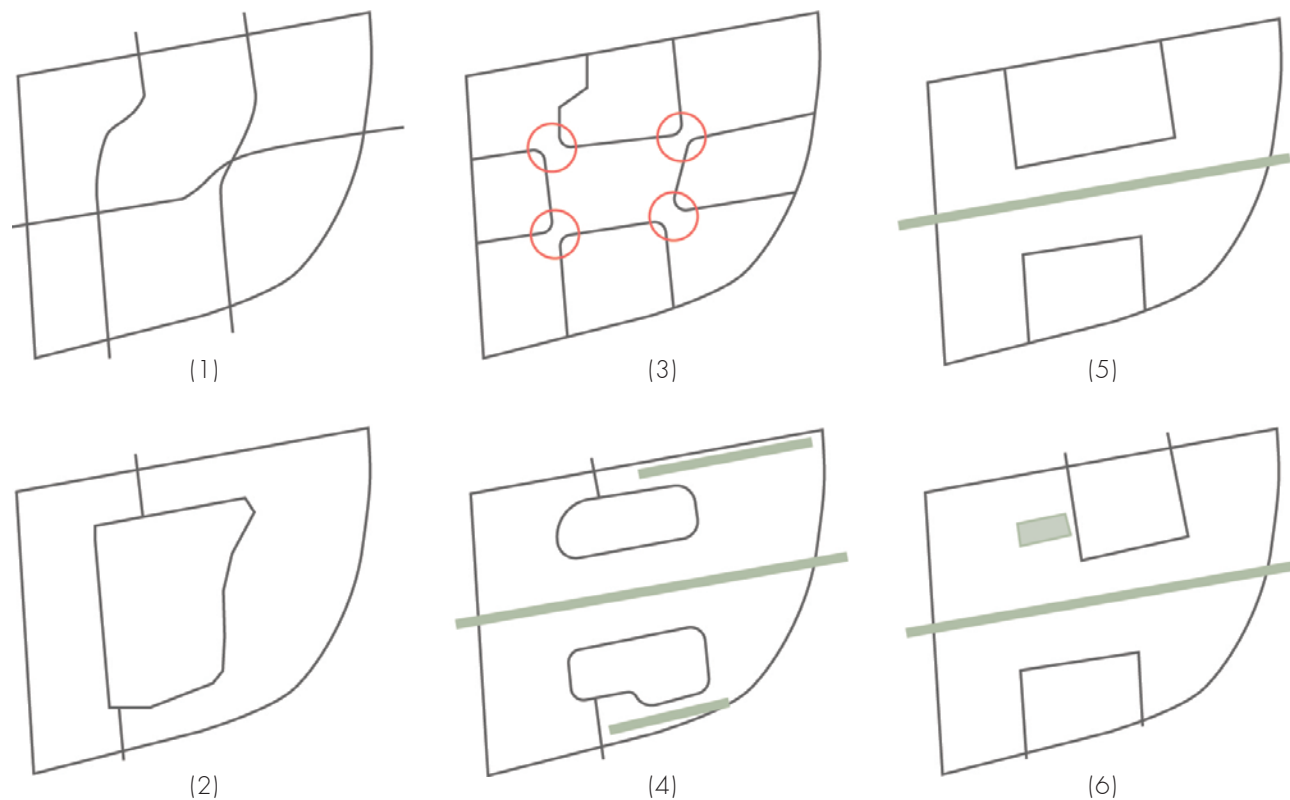


Fig. 8.8 | Options of road and walking system

8.2.3 Road and Walking System

Fig.8.8 shows the options of road and walking systems. (1) is the most accessible plan for cars, while not friendly for the elderly. (2) makes a central walking free zone, but people need to cross the road. (3) creates a continuous walking zone, but space is not enough to work. (4) keeps the central walking zone continuous, but the roads always pass in front of the building. Therefore, use (5) to avoid this. To also reduce the impact of the road to semi-public space, move the road like (6).

The final road system is shown in Fig.8.9.

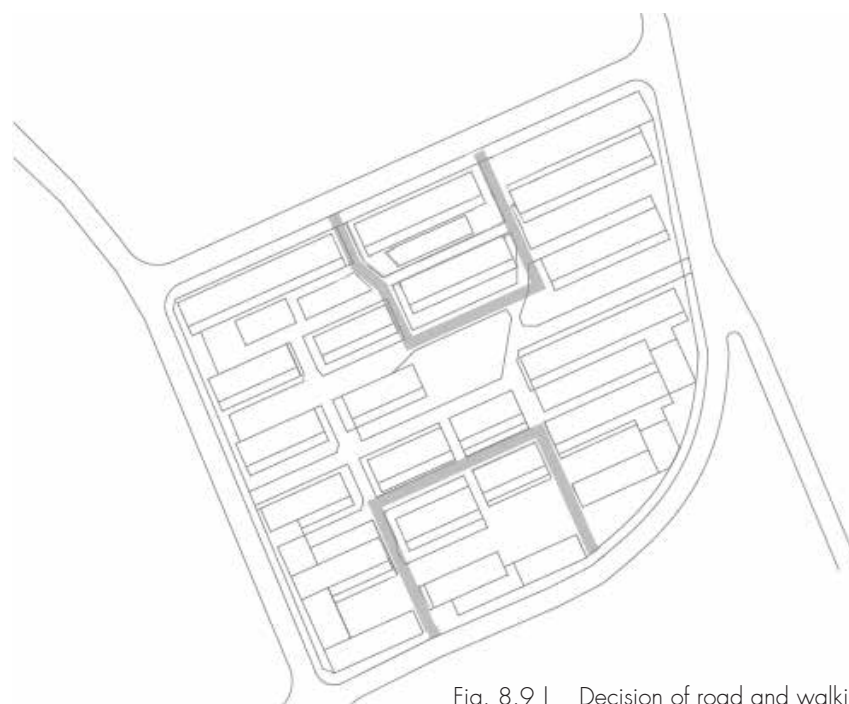


Fig. 8.9 | Decision of road and walking system

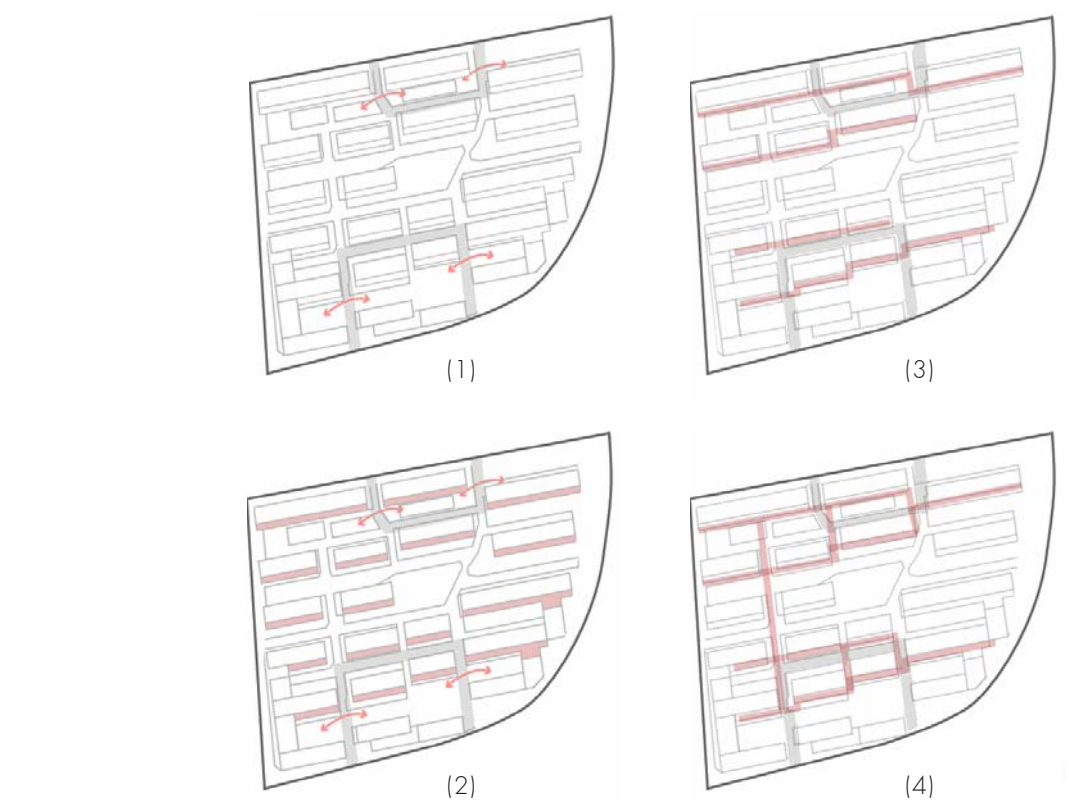
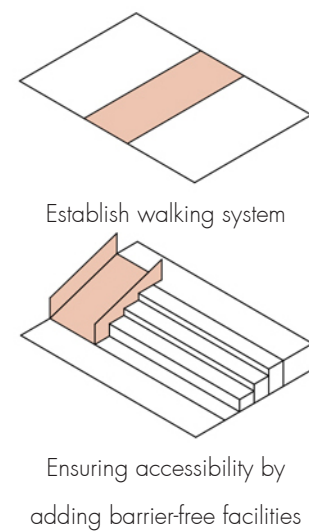


Fig. 8.10 | Options of sky corridor

8.2.4 Link with sky corridor

Although the separation of pedestrians and vehicles is considered in the design of roads, there are still times when people need to cross the road, such as Fig.8.10. (1). As shown in (2), the new workers' estate has the characteristic of having some extra building area on the ground floor, and they extend beyond the building. There is potential to use these parts as the base of sky corridors to cross the roads. (3) is the plan to only build sky corridor cross the street. While (4) is the plan to build both crosses and along the road to form a continuous sky corridor.

To minimize the construction amount, only build a new sky corridor when necessary, and the final sky corridor is shown in Fig.8.11.

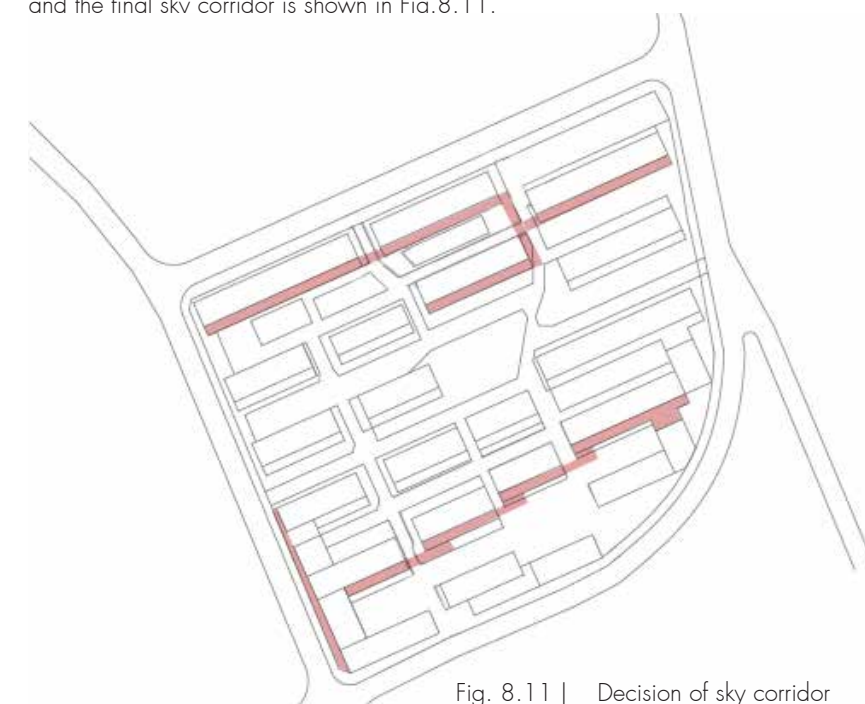
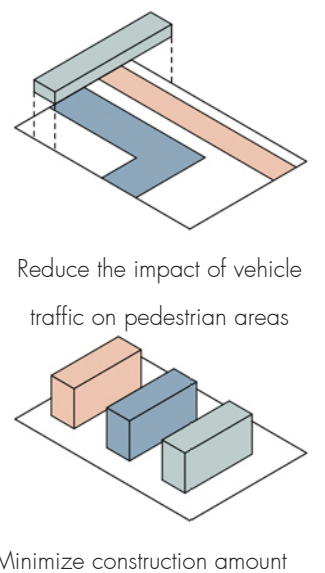


Fig. 8.11 | Decision of sky corridor



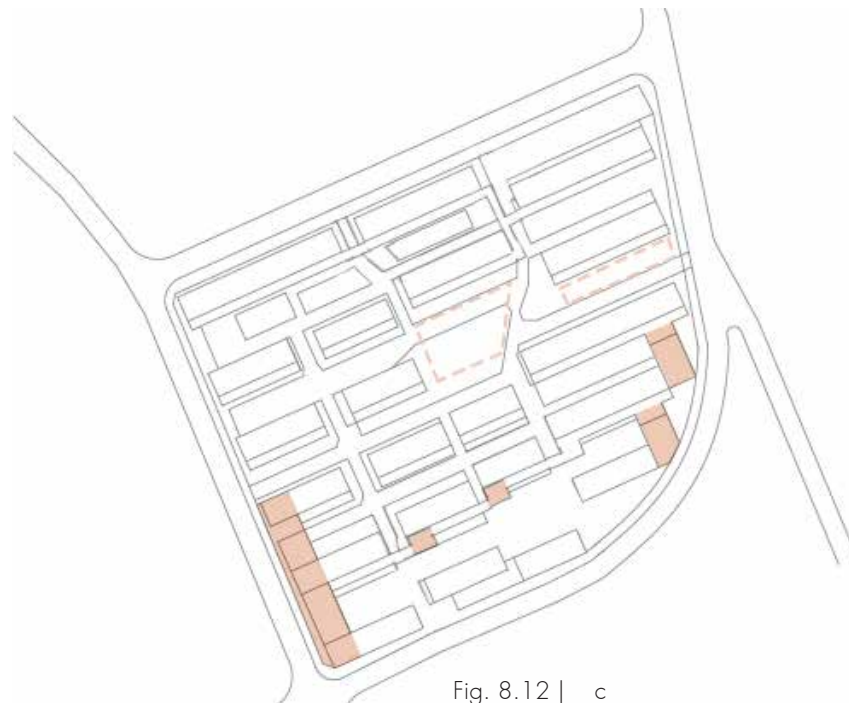


Fig. 8.12 | c

8.2.5 Elderly Service Facilities

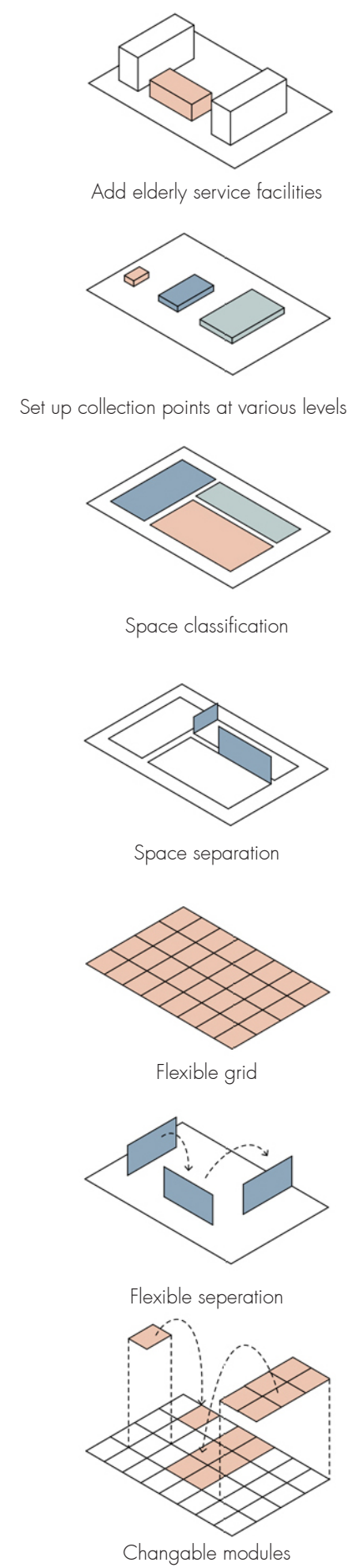
In order to make the life of the elderly more convenient and rich, some elderly service facilities should be added, as shown in Fig.8.12. They are added to the ground floor of the newly built east-west buildings. Sometimes, when connecting the sky corridors, it forms some platforms, these functions can also be added under these platforms. In the central public space, there is the potential to add some flexible and movable service facilities.



Fig. 8.13 | Waste collection points

8.2.6 Waste Collection Points

To collect the waste decoration materials, set up two hierarchies of collection points in the community (Bakaeva, 2018), see in Fig.8.13. The secondary collection points collect the waste directly from the users, so they locate near the building and yards. Three or four buildings share one position. The main collection point is storage and transformation joint to transport these waste out of the community, and also acts as the community lab.



8.2.7 Future adaptivity

To keep the flexibility of the public space, the area is divided into four classes: multifunctional hard surface, specific functional modules, multifunctional open soil, and green buffer area. The proportion of them is shown in Fig. 8.14. The multifunctional areas account for more proportions than specific functional areas.

The multifunctional areas also use the layers from the material toolbox and the modular construction method. But in the design process, only the base material is decided, and no other excessive design is done to limit the activities that occur in this space. In these modules, the users can determine the function of the areas and use them flexibly.

A big space without any design sometimes cannot work as well as imagined. People's different activities affect each other, or because the area is too large, it makes people feel bad to use. Therefore, add some separation to divide the big space into small spaces with a suitable scale. The separations are also flexible.

There are still some activities that need the form of space to provide auxiliary facilities, for these events, use the specific functional modules. To be flexible, all these modules are changeable.

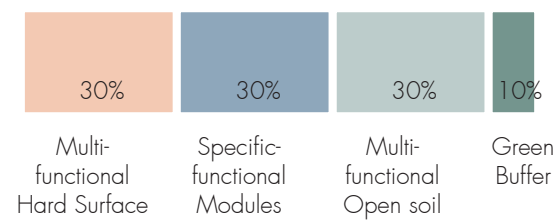


Fig. 8.14| Proportion of multi-functional and specific-functional area

In order to make the space more flexible, provide a changeable framework for public spaces. Place a grid in the entire area, as shown in Fig. 8.15.(1). The modulus of the space is chosen to fit the commonly used modulus of 3m in the building. Fit the public space boundary in the grid, see in (2). Since this is not a newly built estate according to the modulus, but a renovated old estate, the size of the space cannot adequately meet the modulus, so the insufficient excess modulus is supplemented by the green buffer. The road and paths are also in the same modulus. The final grid is shown in (3).

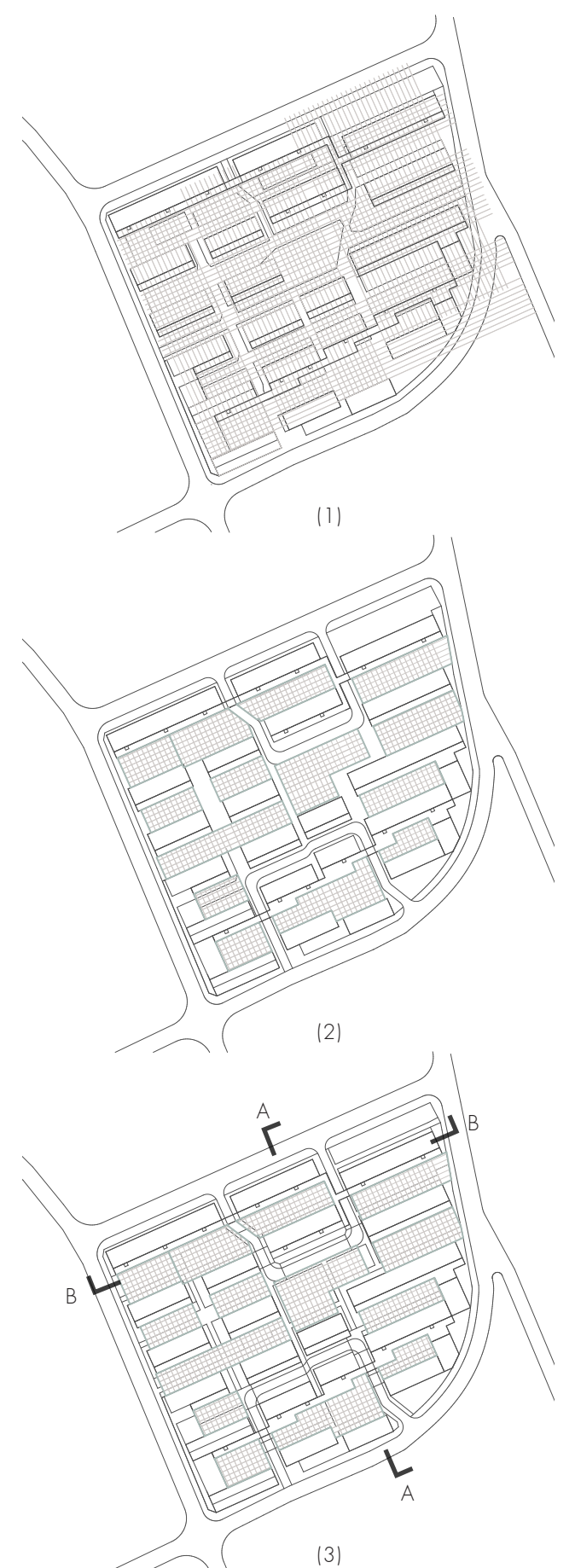


Fig. 8.15| Applying flexible grid to the site

8.2.8 Function

In 8.2.2, the public space is divided into public space, semi-public space, and semi-private space. In 5.3, through interview, investigation, and literature review, there is a list of the elderly's activities. And these activities are divided into four types in 7.3.2, see in Table. 7.1. As the community is a mixed community of both the elderly and also the other people, the public space can be further classified into the elderly activity area and mix activity area.

The proportions of each type of function in the three hierarchies of public space are shown in Fig. 8.16. (1) shows the percentage in semi-private space. This type of public space is the closest public space to the home. Some elderly people have limited mobility and are not suitable for long-distance activities. Also, some daily outdoor activities should be carried out nearby. Therefore, this kind of space is most suitable for the elderly stay dispersed activities. Besides, this type of space should also undertake part of stay gathering and mixed stay dispersed activities. Because young people have less time and frequency of using public space than old people, the proportion of mixed stay dispersed activities is smaller.

(2)Shows the percentage in semi-public space, mix stay gathering accounts for the largest proportion, and the area also assumes the function of stay dispersed and elderly stay gathering. (3) shows the percentage in public space, which is the most open area for elderly stay gathering and mix stay gathering functions.

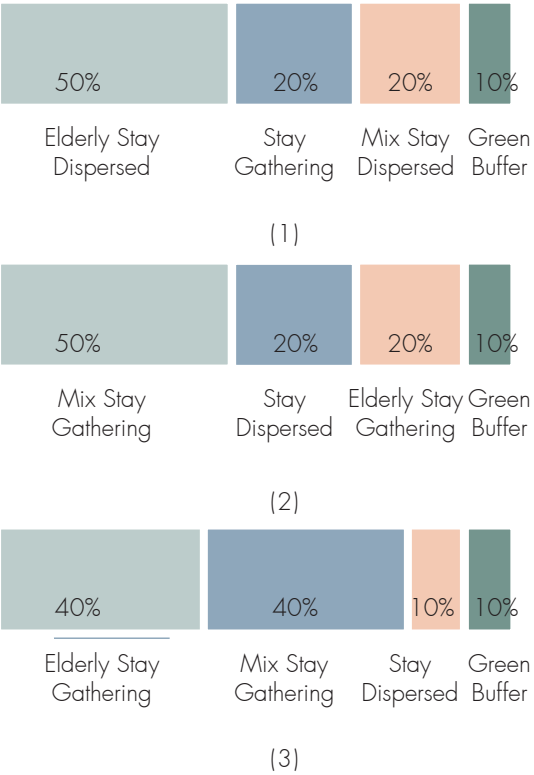


Fig. 8.16| Proportions of different functions

Put the functions into the site, the sections shows the layout and the activities of these spaces, see in Fig.8.17 and Fig.8.18.

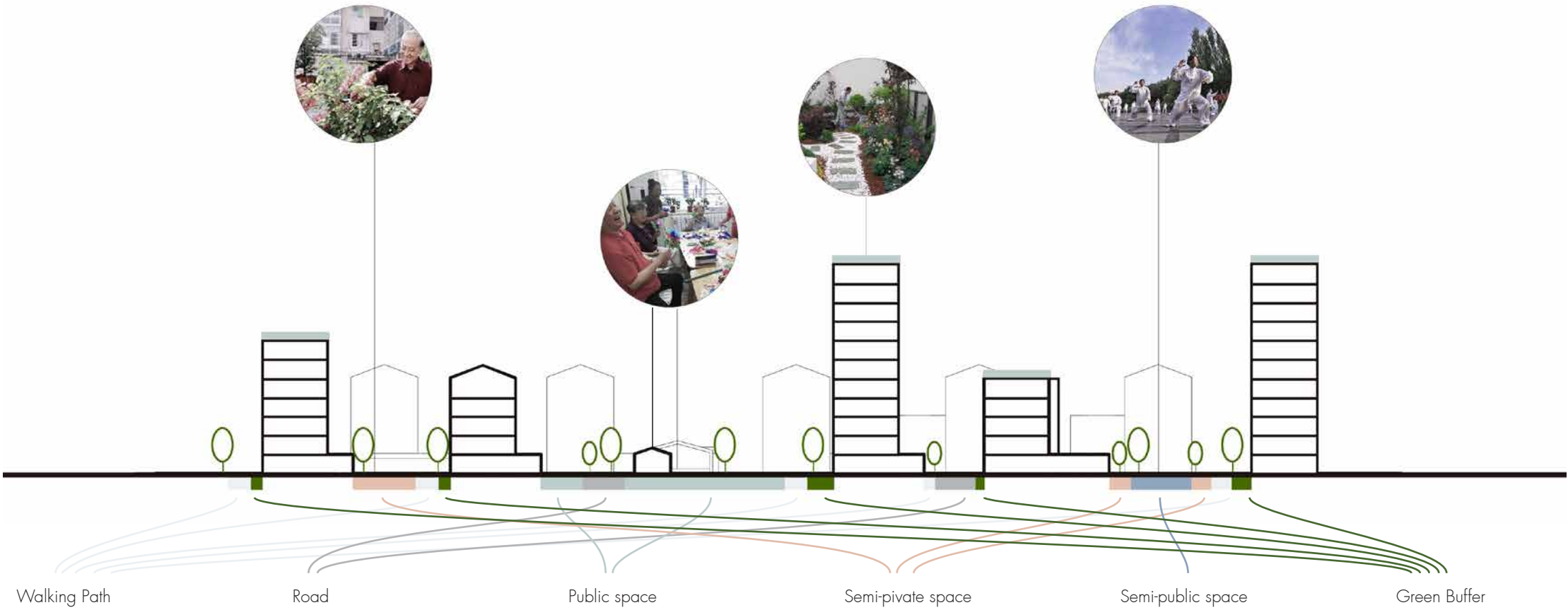


Fig. 8.17| Section A-A



Fig. 8.18| Section B-B

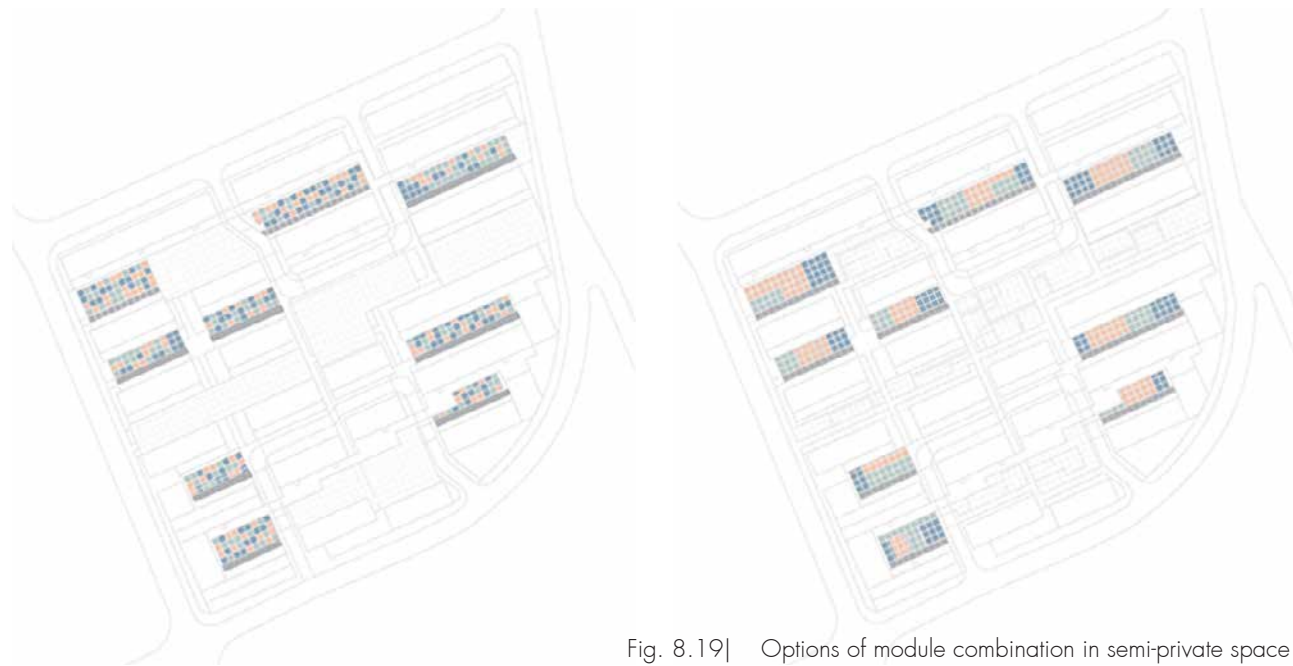


Fig. 8.19| Options of module combination in semi-private space

8.3 SEMI-PRIVATE SPACE



The semi-private space is a courtyard shared by residents of nearby buildings. The following sections will show how the modules are placed to the grid of the area, and zoom to one case to explain the functions, experience, flexibility, and circular construction of such spaces in detail.

- Less public space
- More public space
- Public facility space
- Public space and semi-public space
- Elderly service facilities

8.3.1 Module combination

As mentioned before, in 7.4, there are two types of modules: single-grid module and multi-grid module. Therefore, there are two options to put single-grid or multi-grid modules to the grids, as shown in Fig.8.19. The single-grid mode has a limitation on the scale of space and makes a homogeneous space. The multi-grid mode has a feature that tends to be more public or private to divide different activities, but there will be less variety.

As shown in Fig.8.20, the level of openness of the public spaces are different. Therefore, when the openness on both sides is different, multi-grid modules are applied. When the openness on both sides of the semi-private space is the same, apply single-grid modules, as shown in Figure 8.21. While designing and guiding the use of space, increase the diversity of space.

- More public space
- Stay gathering
- Elderly stay dispersed
- Mix stay dispersed

Fig. 8.20| Different levels of openness of public space

Fig. 8.21| Decision of module combination in semi-private space

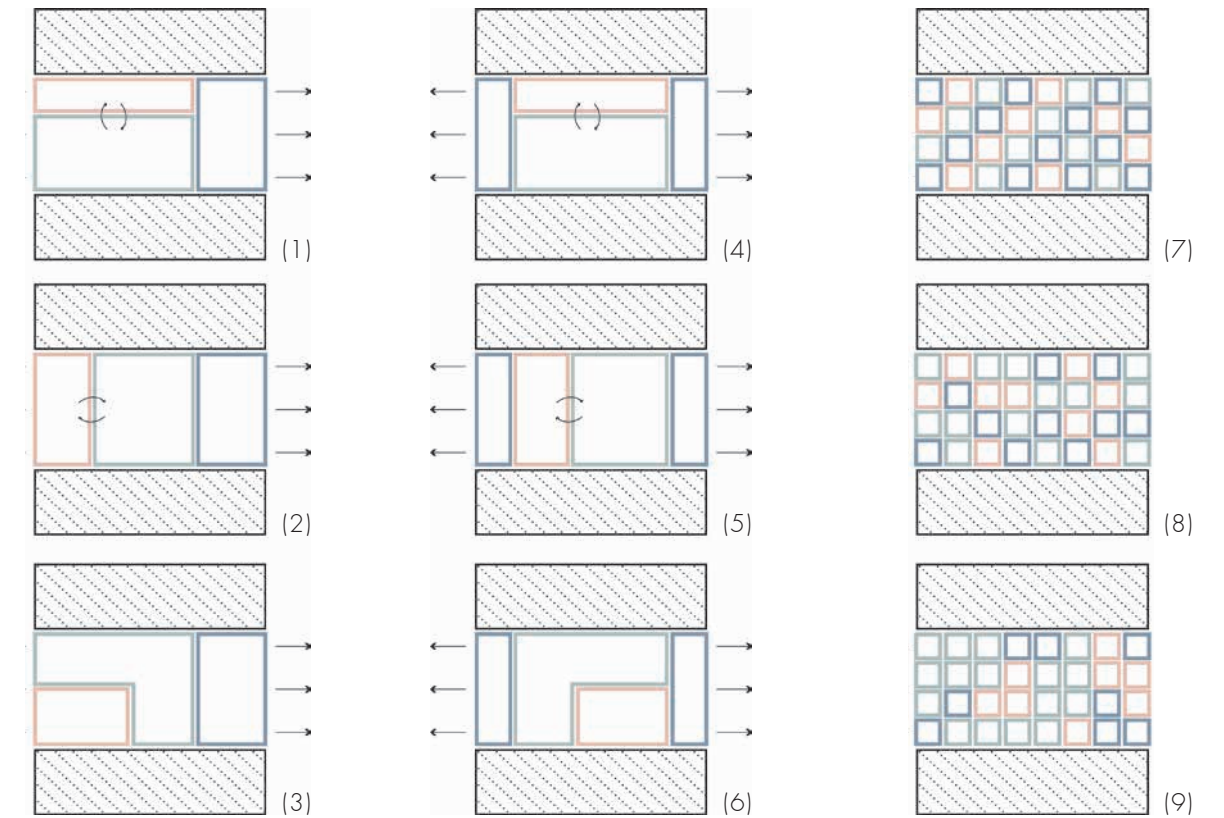


Fig. 8.22| Options of module layout in semi-private space

8.3.2 Module layout

Fig. 8.22 shows the options of module layout in semi-private space. (1)|(2)|(3) shows the situation when one side of the semi-private space is more public space. The stay gathering function area locates on this side. Considering the size, direction, and diversity of the space, the other two types of space (elderly stay dispersed and mix stay dispersed) can be arranged vertically, horizontally, or enclosed to divide the remaining space.

(4)|(5)|(6) shows the scenario that the openness on both sides is different. For example, one side is a public building, and the other side is public space, or the hierarchies of public space are different on the two sides. The two sides are both open, so the stay gathering function area locates on both sides. Similarly, the other two types of space are divided as mentioned before.

(7)|(8)|(9) shows the situation of using single-grid modules. (7) is the most mixed option, adjacent grids place modules with different functions. (9) is the most combined option, several adjacent grids place modules with the same function to form an area. In this way, the accessibility of the space can be ensured, mutual influence can be reduced, and mean-

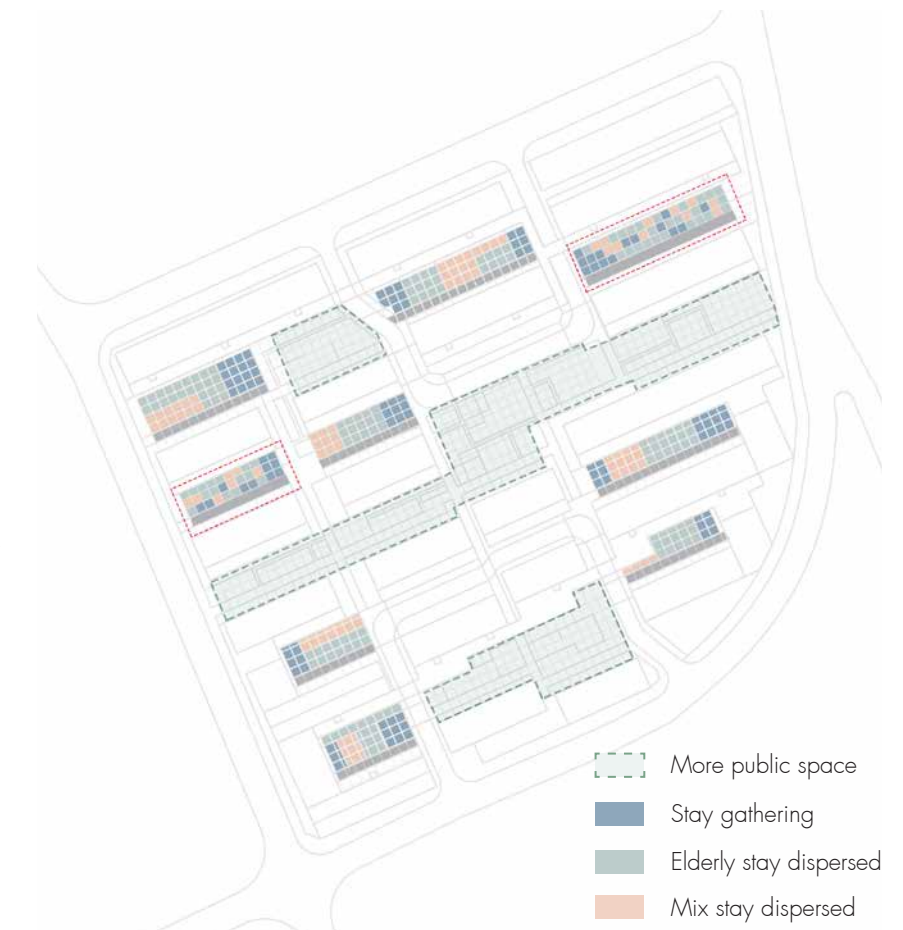


Fig. 8.23| Decision of module layout in semi-private space

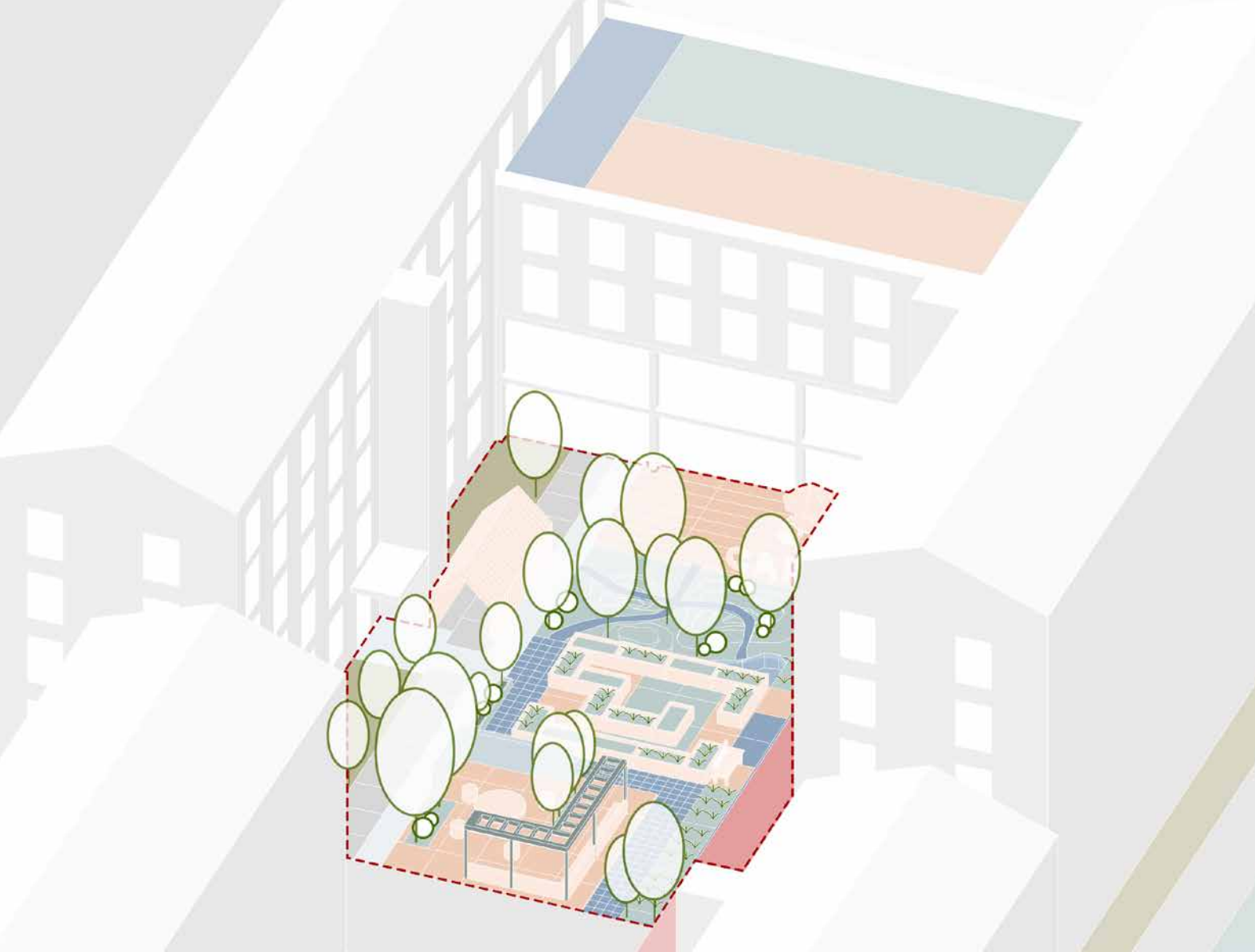


Fig. 8.24| Example of semi-private space

while, the space can have vitality and diversity.

Following the ratio of various functional areas mentioned in 8.2.8, after many attempts, the final module layout is as shown in Fig. 8.23.

8.3.3 Case

Choose a semi-private space in the southwest corner as an example, as shown in Fig. 8.25. The west side is the elderly service building, and the east side of it links to the semi-public space. The overall layout of this area is as shown in Fig.8.24

This area contains four main parts of public space, the buffer area, and the passing area. Holding the role as one of the collection points, there is also a storage facility in the yard. There used to be a building in this position. To improve the public space quality, the building, together with another one, is demolished and rebuilt into a new one. This area is an extra open space created by the regeneration.

In this public space, the residents from the buildings surrounding it can share the area. It will be mostly used by the elderly residents for there daily gardening, staying outside alone, with family or with friends. The other residents can also have access to share this area. The first two floors of the newly built side building have the function of elderly service facilities as the elderly daycare center.

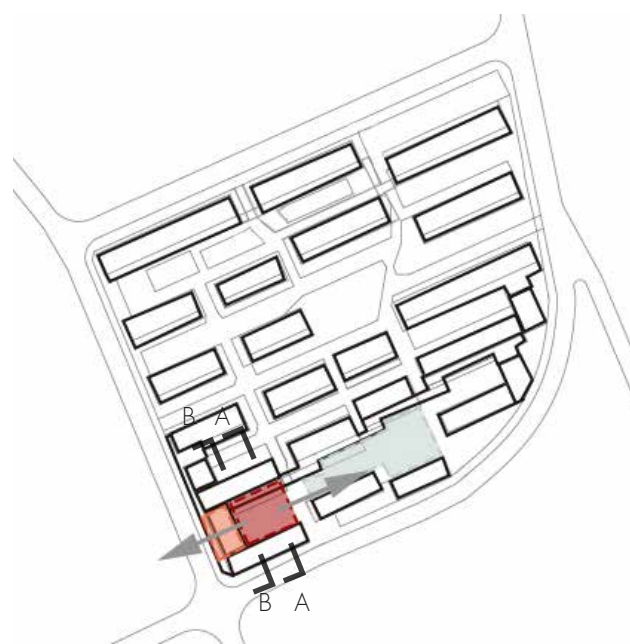


Fig. 8.25| Location of the example semi-private space

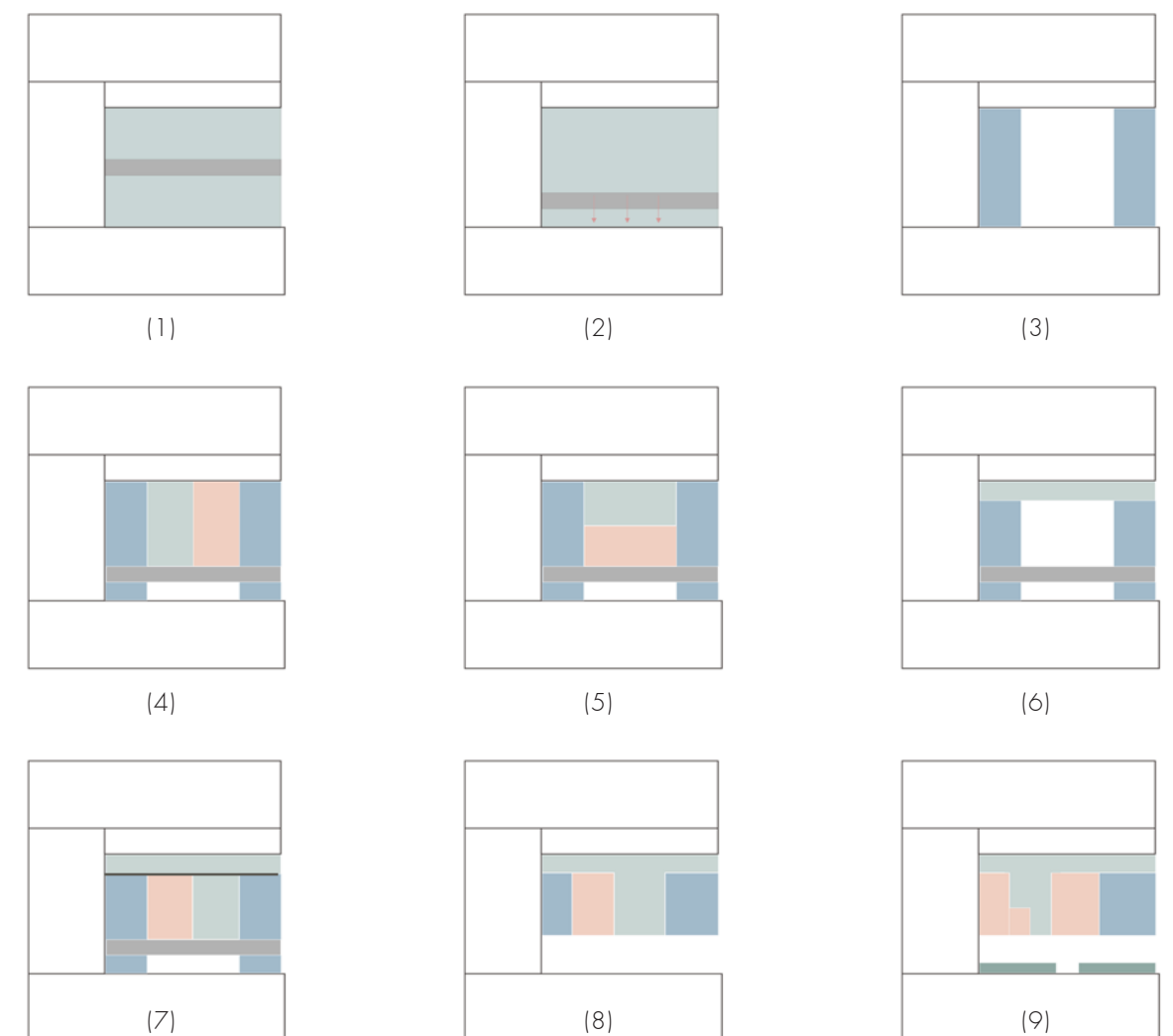


Fig. 8.26| Options of the layout of the semi-private space

There are two options for the location of the passing area, in the middle linking to the daycare center, as shown in Fig.8.26. (1) or close to the south building (2). As there is only residential building entrance on the south side, to facilitate access, while occupying the area covered by the shadow of the building, choose option (2). As introduced before, both sides of the area have public functions, so the stay gathering area is located on both sides, as shown in (3).

Then the layout of the elderly stay dispersed area and mix stay dispersed area have two options, as shown in (4) and (5). To get the most sunshine in the planting area, the ground urban farming area is located along the north side of the area, as shown in (6). There needs to be a walking path between the planting area and the stay gathering area to guarantee the accessibility to other modules. Therefore, mode (4) is more suitable for this layout, see in (7). In this plan, the mix stay gathering area can get the same good sunshine.

The proportion of the three types of area, shown in (8), obeys the conclusion in 8.2.8. The elderly stay dispersed area occupies the largest proportion, mainly with the function of planting. Some other stay dispersed functions, such as rest, can be added somewhere in it. The stay gathering area on the east is the most open area, shelter, separation, and specific furniture should be placed to create a comfortable place for people to gather together for a long time to stay. The stay gathering area on the west tends to be the activity space that serves the public building with flexible functions. And the mix stay dispersed area could be an open green area for all kinds of residents spare their time there. Therefore, the multi-functional and specific-functional modules, shown in (9), also follow the conclusion in 8.2.8, see legend in Fig.8.14.

Lastly, with the layout of each function, divide the area into grids as mentioned in 8.2.7, arrange the functions into the grid, and put proper modules into the grid, as shown in Fig.8.27. The eye-level experience of the space is shown in Fig.8.28.

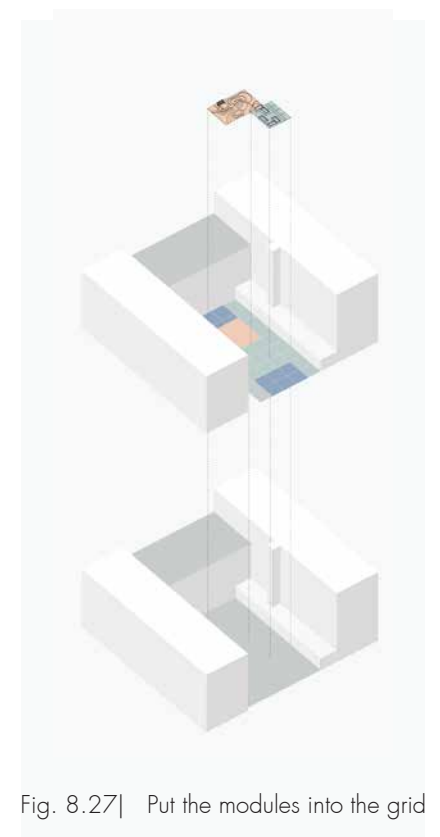


Fig. 8.27| Put the modules into the grid



Fig. 8.28 | Eyelevel perspective of the semi-private space

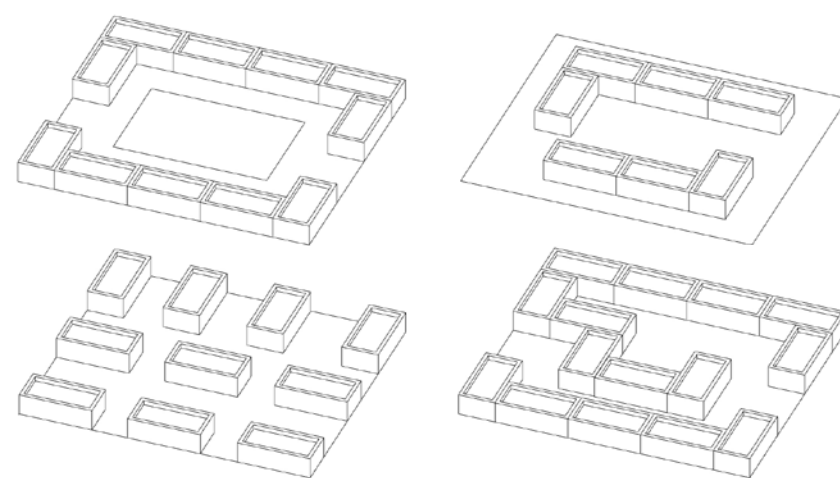


Fig. 8.29 | Functional flexibility of the semi-private space

8.3.4 Future adaptivity

The flexibility of the area is embodied in the multifunctional elderly stay dispersed area. As one of the possible functions, it could be filled with planting beds. The layout of the planting bed is flexible to create the space as people want, as shown in Fig.8.29, by applying reversible assembly methods.

Besides, this hard paved area could also hold other activities. As people's needs for different activity spaces change, the function of this space can easily be changed.

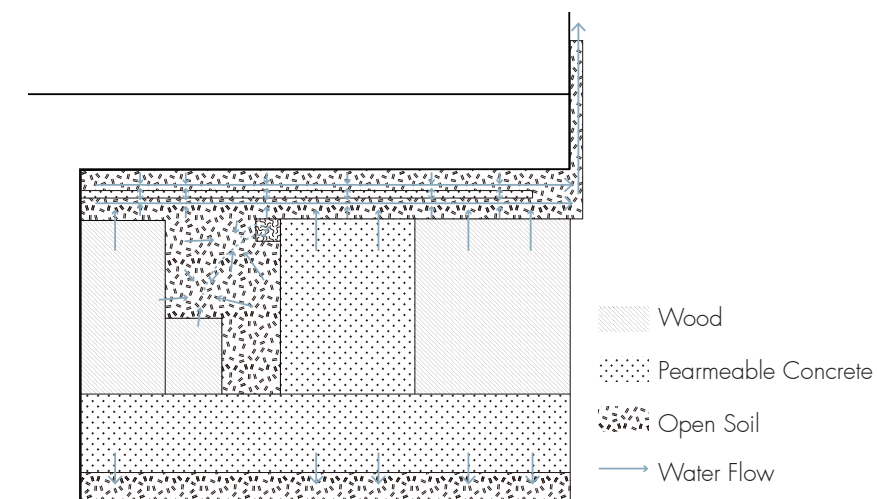
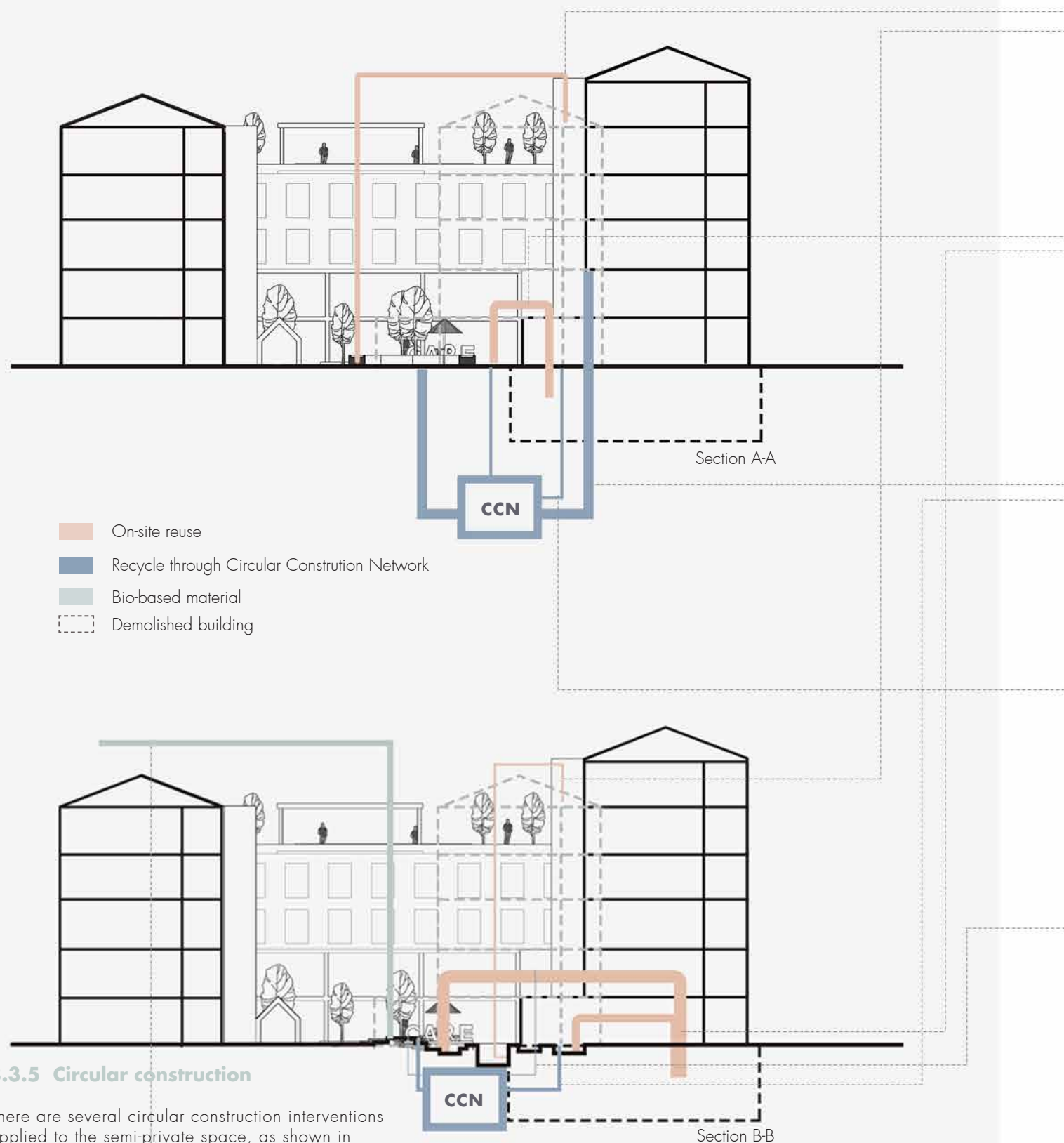


Fig. 8.30 | Water flexibility of the semi-private space

The water permeability is also considered in the design. Firstly, the materials used, such as wood and permeable concrete, are permeable for water. The open soil is also naturally permeable, which infiltrates the rain instead of running it off. Use the height difference of the landscape to form a wadi, guiding the water flow that cannot be penetrated immediately, as shown in Fig.8.30.

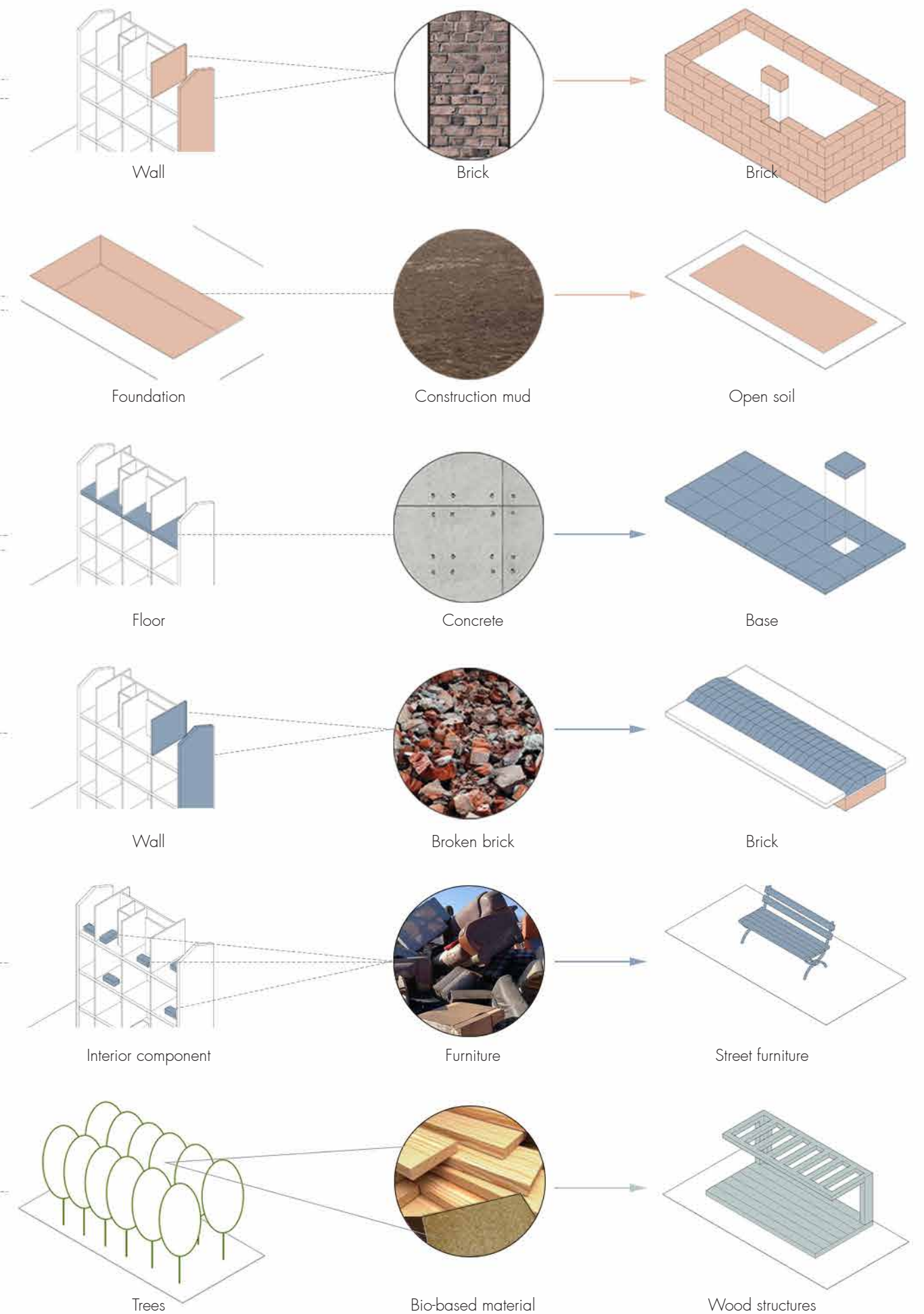
The overflow water is collected in the middle of this area as landscape or for irrigation, and the water cannot storage here flows as the arrow to the next yard for use.



8.3.5 Circular construction

There are several circular construction interventions applied to the semi-private space, as shown in Fig.8.31. It shows where the materials are generated from the original buildings, what are the original materials, and how the materials are circularly used in public space. There are two sections of the public space, and both on-site reuse and off-site recycling through Circular Construction Network are implemented. The materials being circularly used are mainly aggregate. Besides, bio-based materials are also used.

Fig. 8.31| Circular material flow in semi-private space



8.4 PUBLIC SPACE

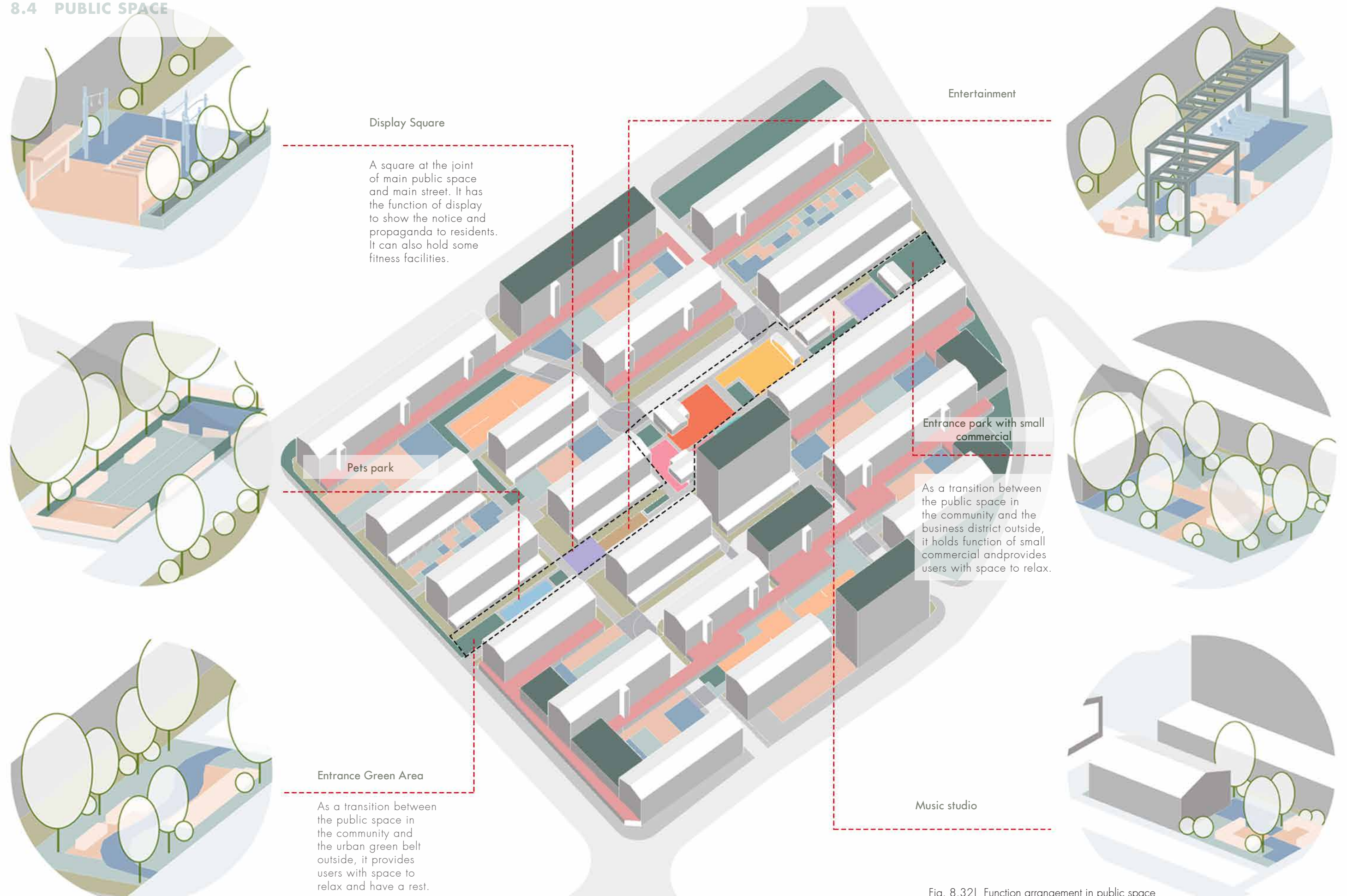


Fig. 8.32| Function arrangement in public space

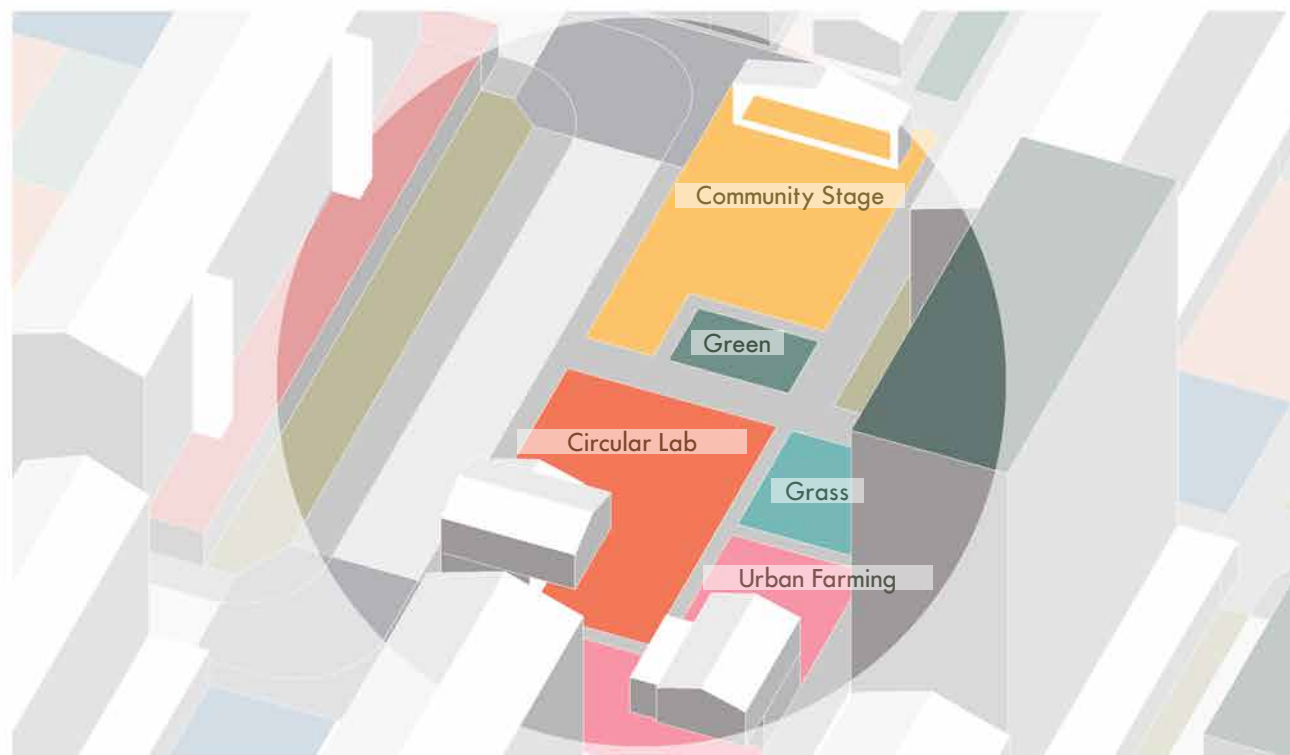
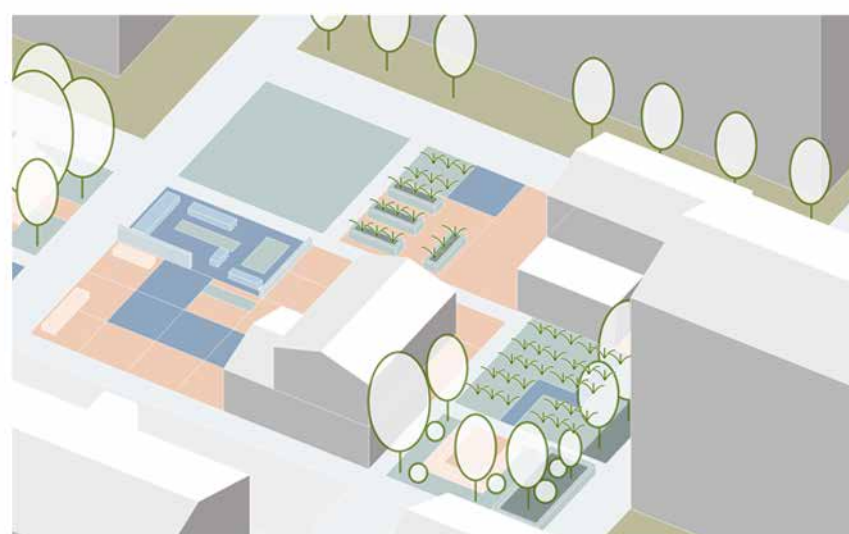


Fig. 8.33| Scenario A of the central public space



Fig. 8.35| Scenario B of the central public space



The public space is the most open space in the community. It can be shared with both the residents and the people from outside of the neighbourhood, as the linkage of the urban green corridor and business district. The following sections will show how the functions are placed to the grid of the area, the flexibility, and circular construction of the space in detail.

8.4.1 Elderly adaptive functions of public space

In the main public space, it is a walking free zone connecting small spaces with different functions, as shown in Fig.8.32. The entrances on the two sides are green areas as the transition space. Along with the middle public space, most of the functions are for elderly staying gathering. For example, the functions of pet parks for the elderly accompanying pets, the display square for exercise, the entertainment gallery for card games and chess, the music studio, and also spaces for flexible and mix functions.

The function of the central public is shown in Fig. 8.33 to Fig.8.35.

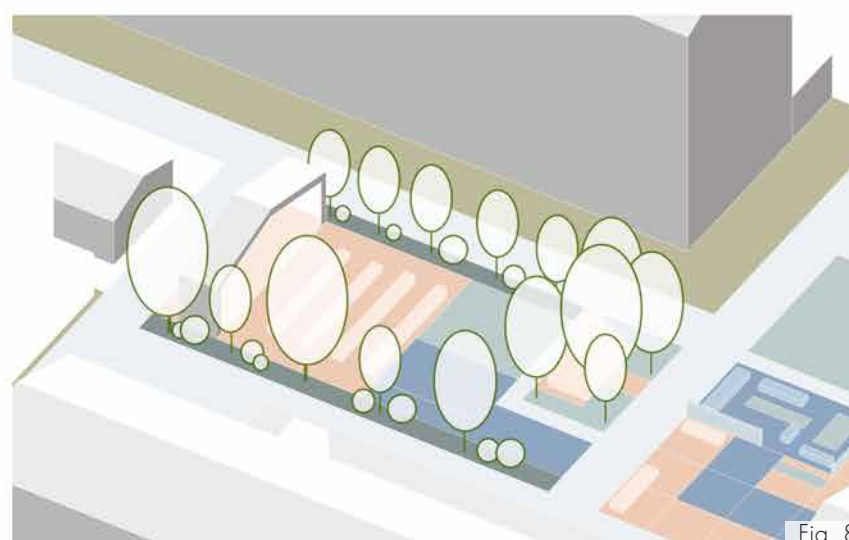
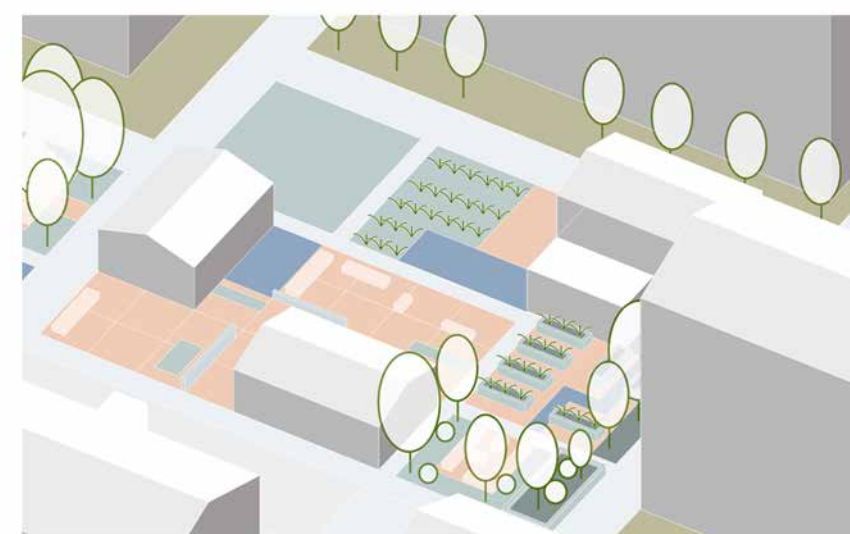


Fig. 8.34| Centralized lab and community stage



The central public space can hold the functions of community stage, market, circular lab, urban farm, and mix functions.

8.4.2 Future adaptivity

Fig. 8.33 and Fig.8.35 also show the flexibility of the public space. Fig.8.34 shows the more paved area scenario of the layout. The modules of the circular lab are located together, and the shelter is folded as a stage. Fig.8.36 shows the less paved area scenario. The modules of the circular lab are separated, and the tent is unfolded as the shelter of the community market. The changeable structures make the function of the area variable. There are also areas with no specific function default for the flexible use of the residents. The structure and furniture modules on the square are all changeable and permeable to adapt the future changes.

Besides, urban farming, grass, and greening areas keep a high proportion of open soil to make the area ecological friendly. The hard surfaces are all water-permeable to be adaptive to the increasing rain.

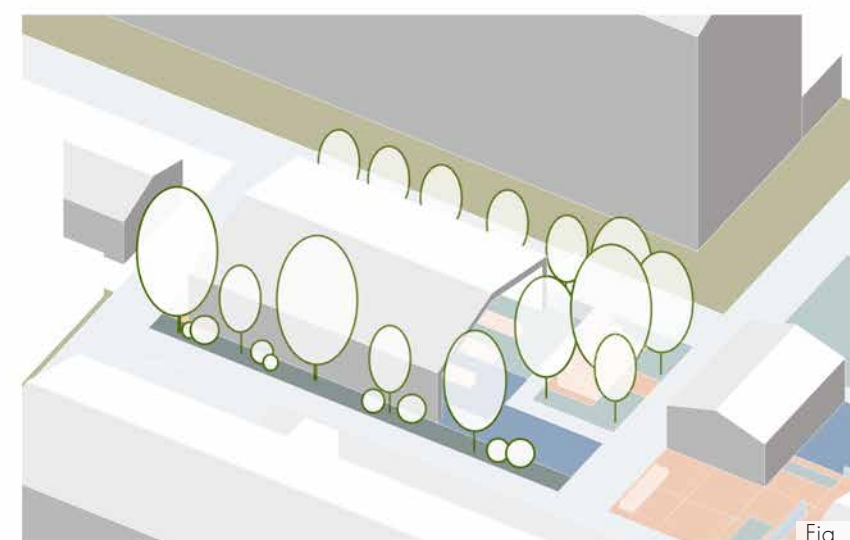


Fig. 8.36| Dispersed labs and community market



Fig. 8.37 | Eyelevel perspective of the central public space

8.4.3 Circular lab

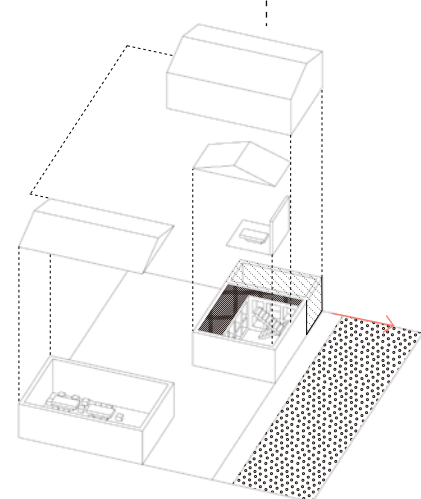
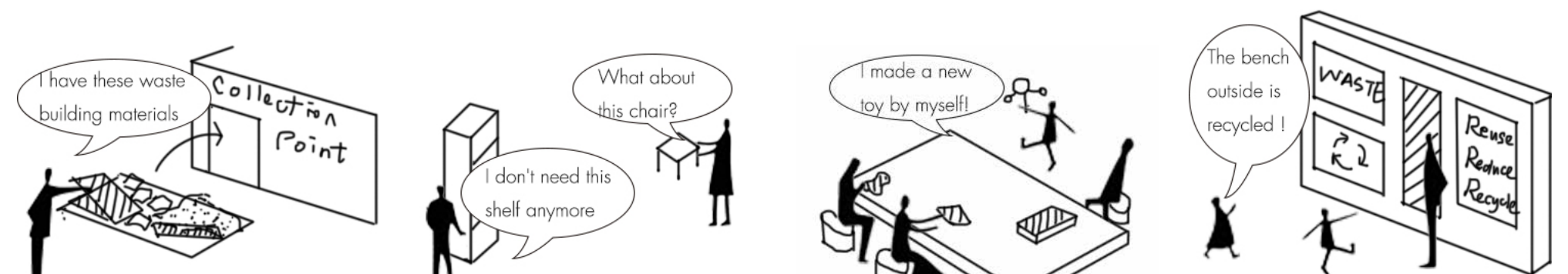


Fig. 8.38 | Community circular lab and the activities



The community circular lab is made of prefabricated modules. They use the aggregates and components from old buildings or can even use the whole module from the old buildings. These modules can be assembled together or distributed. The eye-level spacial experience is as shown in Fig.8.37. The assembling process is reversible, as shown in Fig.8.38.

The circular lab can hold the functions of the main collection and storage point of CDDW, for residents to exchange unwanted furniture, to carry out DIY workshop activities with CDDW, and to promote the circular construction.

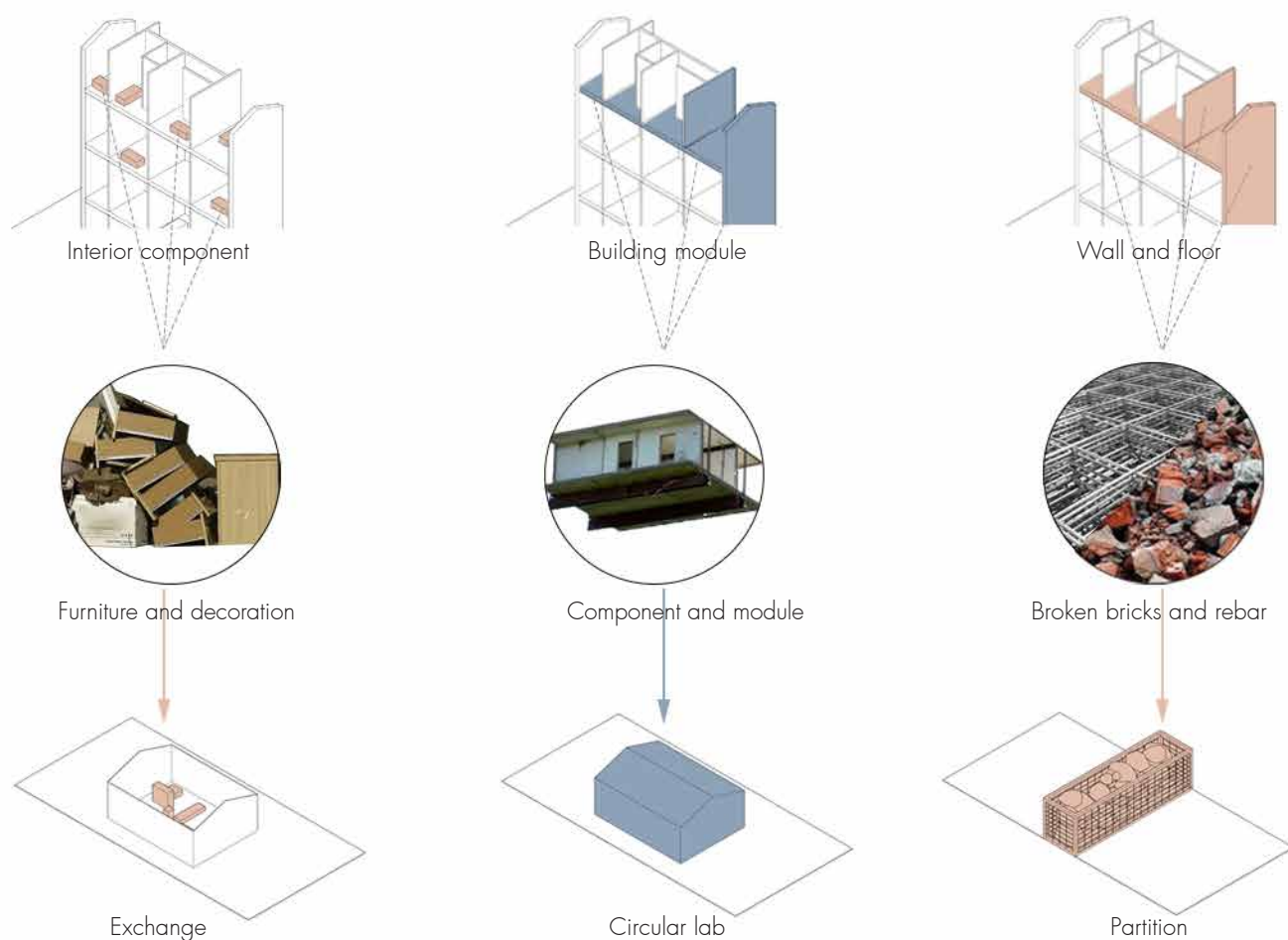
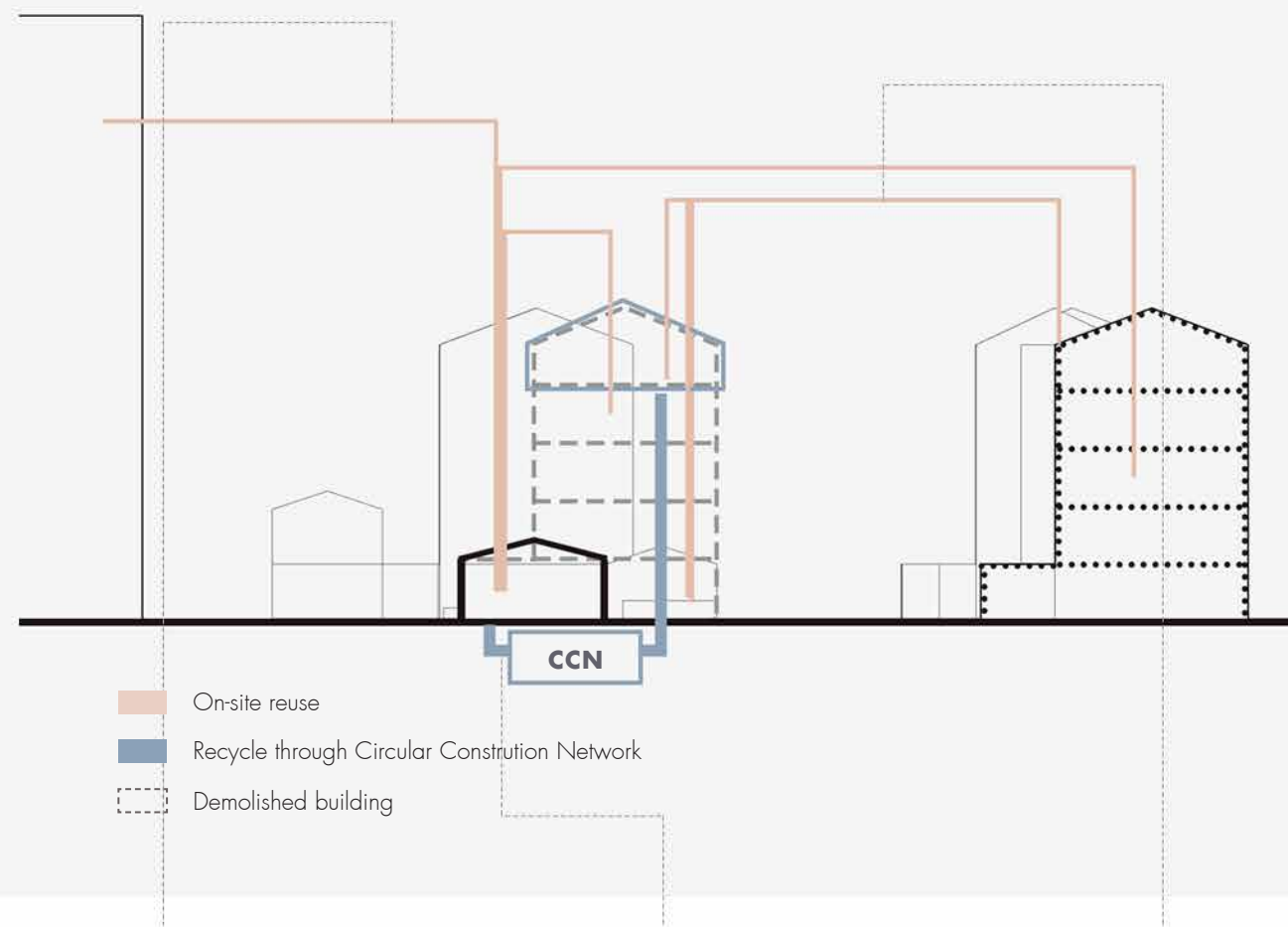


Fig. 8.39| Circular material flow in public space



Fig. 8.40| Semi-public space A

8.4.4 Circular construction

There are several circular construction interventions applied to the public space, as shown in Fig.8.39. Besides the reuse and recycling of the aggregates like the circular use in the semi-private area, such as the construction of partition made of broken bricks and rebar. There is also circular use of components and modules of the old buildings.

The components of interior components can be taken to the circular lab to be exchanged so that they can be on-site reused by people who need them. And when the components of the building structure or the whole module of the original building is demolished integrally, after maintaining or remanufacturing, they can be turned to be prefabricated modular buildings. These modules can be used to be the public buildings or as infill of new modular residential buildings.

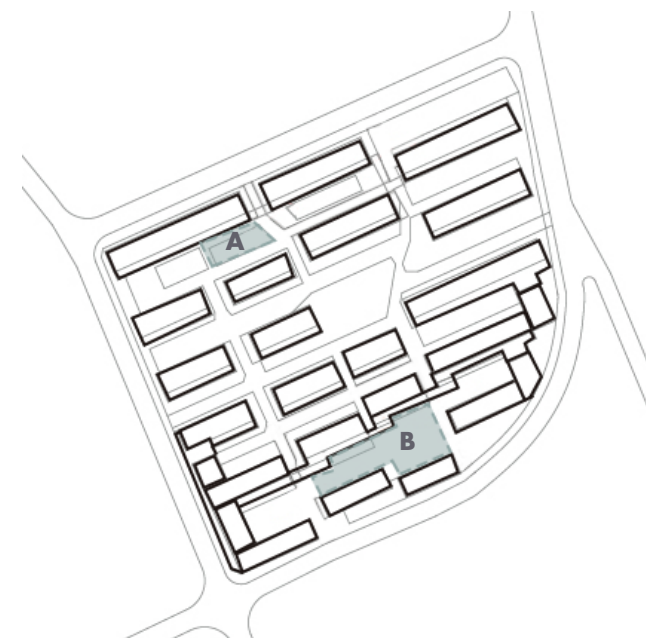


Fig. 8.41| Locations of semi-public spaces

8.5 SEMI-PUBLIC SPACE

8.5.1 Functions of semi-public space

The semi-public space is the in-between open space in the community. It can be shared with the residents as a gathering space. The function of semi-public space is mainly for mix stay gathering, partially for the elderly, and stay dispersed, as shown in Fig.8.44(1) and (2). There are two semi-public spaces in the sample site, as shown in Fig. 8.41.

The semi-public A, as shown in Fig. 8.40, mainly serves the north part of the community. As there are extra floors added to the buildings in this part as social housing, there is more space for mixed users instead of only for the elderly. The facilities and squares are arranged for sports and exercise. The semi-public B, as shown in Fig.8.42, is a more synthesized space, including space for stay gathering (square and grassland) and dispersed (urban farms).

The following sections will take the semi-public B as an example, and show the flexibility, and the circular construction of the space in detail.

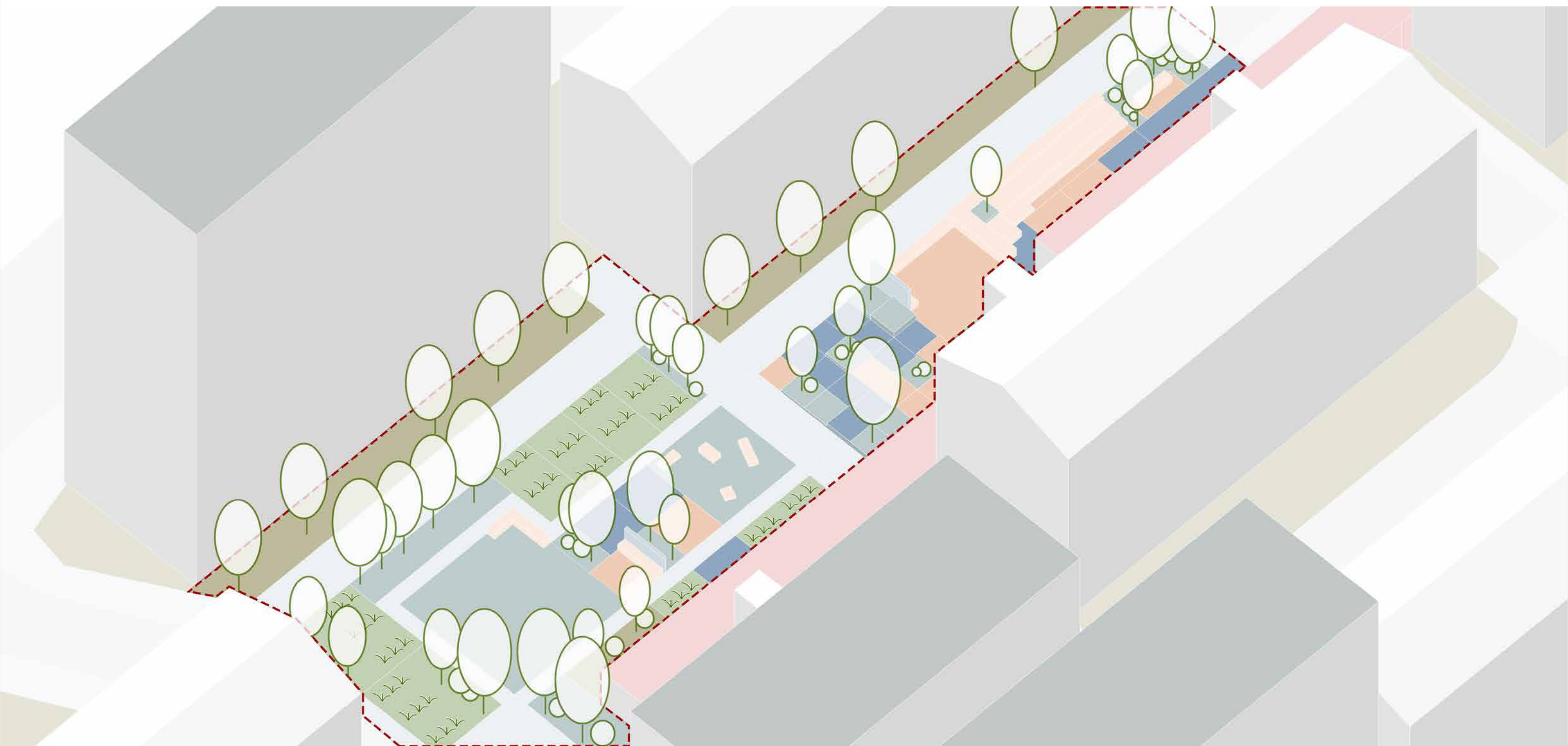


Fig. 8.42| Semi-public space B



Fig. 8.43| Eyelevel perspective of the multi-functional semi-public space



Fig. 8.46| Eyelevel perspective of the changeable semi-public space

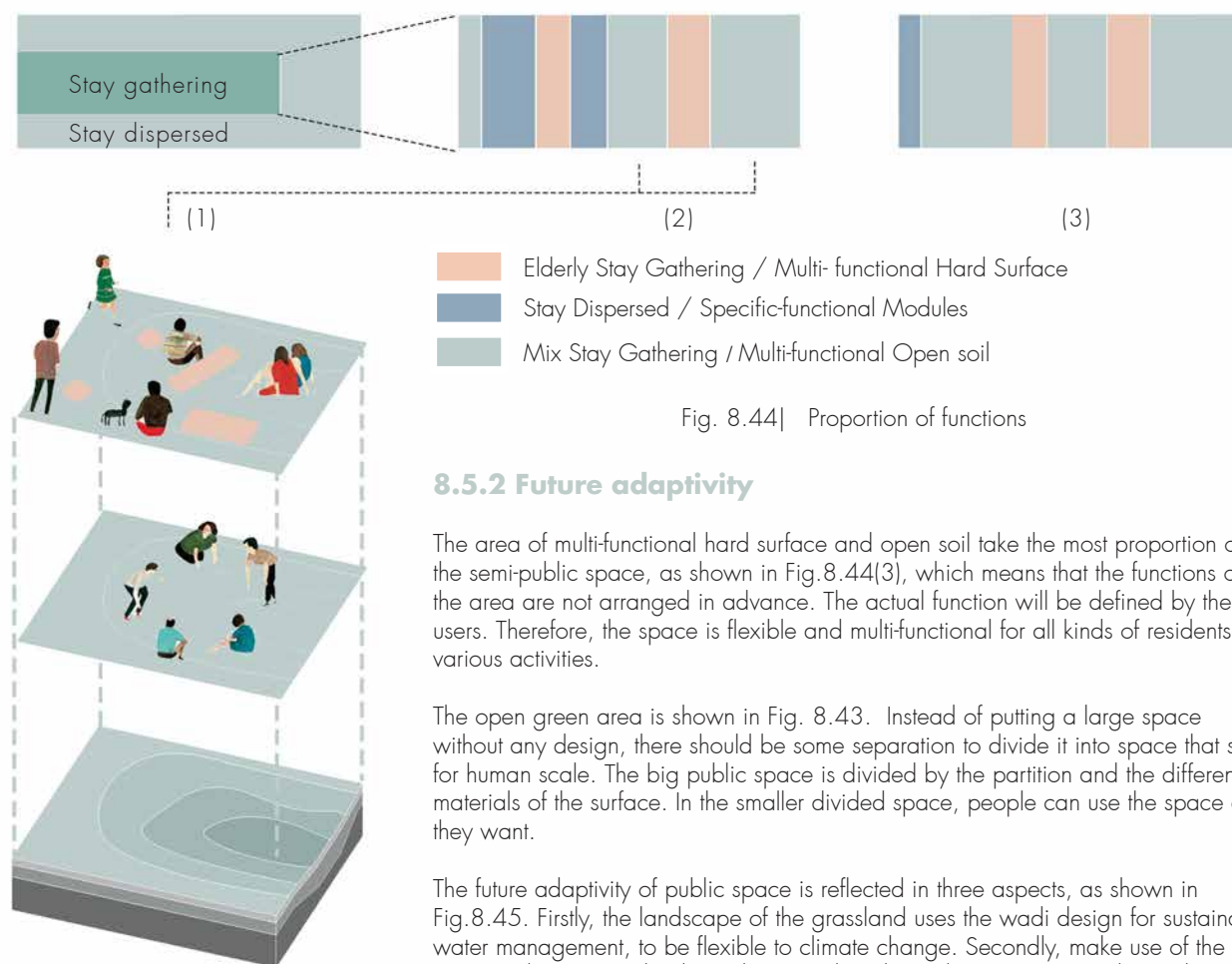


Fig. 8.44| Proportion of functions

8.5.2 Future adaptivity

The area of multi-functional hard surface and open soil take the most proportion of the semi-public space, as shown in Fig.8.44(3), which means that the functions of the area are not arranged in advance. The actual function will be defined by the users. Therefore, the space is flexible and multi-functional for all kinds of residents for various activities.

The open green area is shown in Fig. 8.43. Instead of putting a large space without any design, there should be some separation to divide it into space that suits for human scale. The big public space is divided by the partition and the different materials of the surface. In the smaller divided space, people can use the space as they want.

The future adaptivity of public space is reflected in three aspects, as shown in Fig.8.45. Firstly, the landscape of the grassland uses the wadi design for sustainable water management, to be flexible to climate change. Secondly, make use of the grass as the open soil to keep the natural ecological green area. Lastly, as discussed

Fig. 8.45 | Flexible semi-public space

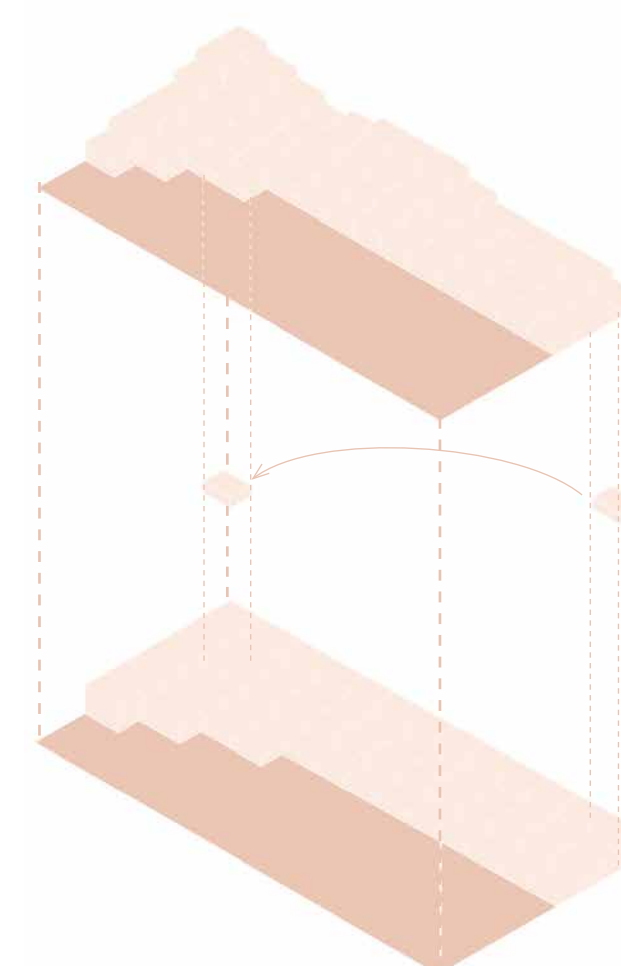


Fig. 8.47| Flexible furniture in semi-public space

before, the function of the space is free for users to choose. Make use of the movable separations like chairs to limit a border of activities of different people, but people can still communicate with others easily. Therefore, the area is also flexible for functional changes.

There is another example of changeable public space design, as shown in Fig. 8.46. The stairs in the public space are reversible, which corresponds to the principle of circular construction and flexibility. The modules that make up the entire step are made of bio-based material. The modules can be assembled and separated easily so that they can be reuse directly to other space, which decreases the recycling demand. Also, the reversible modules can be joined free as people want to form a changeable area, as shown in Fig.8.47. The bio-based modules can be changed by the residents to make the space flexible for functional changes.

8.5.3 Circular construction

There are several circular construction interventions applied to the semi-public space, as shown in Fig.8.48. It shows a section of the semi-public B. In addition to the methods already mentioned above, the following techniques are also applied in the semi-public space. For example, recycle the materials into prefabricated modules by circular construction network, reuse the materials on-site as modular products, and process the bio-based materials into prefabricated modules.

In general, all these aggregates and bio-based materials are reused or recycled into modular products. Therefore, the elderly adaptive functions, future adaptivity, and circular construction are integrated together in design.

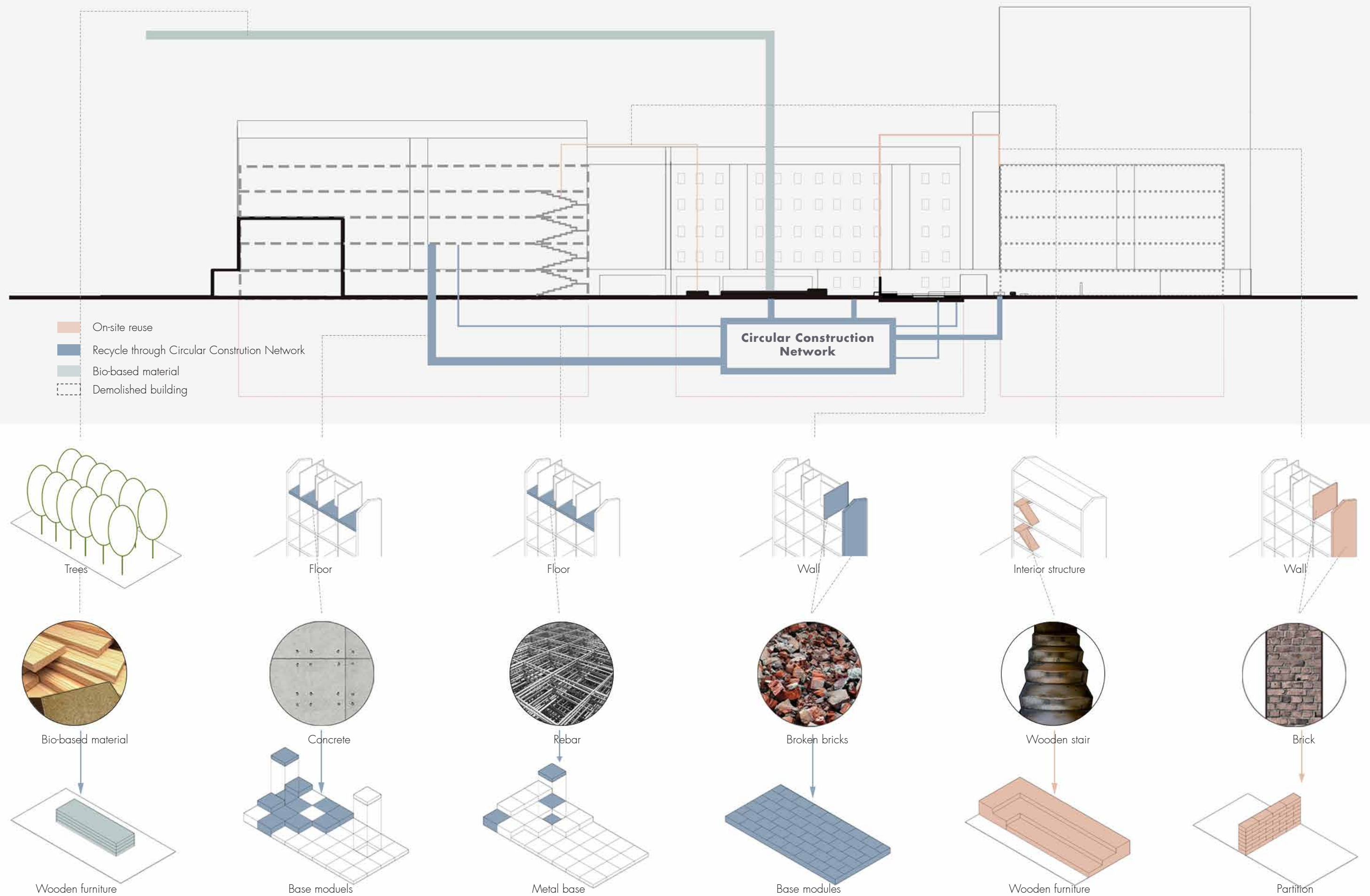


Fig. 8.48| Circular material flow in semi-public space

8.6 EVALUATION

The regenerated building area in total is 8667m². Take brick and concrete as an example. The demolition brick waste is 3473733.6kg, and the concrete demolition waste is 7776899.1kg. The construction brick waste is 130005kg, and the concrete construction waste is 82336.5kg. The total brick waste during the regeneration is 3603738.6kg, and the concrete waste is 7859235.6kg.

The public space area in total is 21402m². The area where recycled concrete boards can be applied is 2499m². This can make use of 4,198,320kg of waste concrete. The area where recycled bricks can be used for pavement is 2408m², and where bio-based can be used for pavement is 602m². This can make use of 1300320kg of waste bricks and 301000kg of bio-based materials.

Each planting bed requires approximately 6480kg of waste bricks, in total, can reuse 777600kg of waste bricks on-site. The partitions in total can reuse 64800kg of them.

To sum up, the regeneration of public space use 4,198,320kg of waste concrete and 2,142,720kg of waste brick. This means that it makes use of 54% of the waste concrete and 60% of the waste brick. Although the recycled concrete and bricks used in public spaces will be processed and transported through a circulation construction network, not necessarily all from local sources, but the on-site reuse of 23% of the waste bricks is using the waste generated by building regeneration. And in total, through this circular regeneration method, the public space regeneration process in total save 34 % of new materials.

At the same time, through the design, the quality of public space is improved, it can better support the activities of the elderly, and it is easier to adapt to future changes.

8.7 CONCLUSION

- Using the strategies for general spatial regeneration design following the principles

- Reduce unnecessary construction and only regenerate buildings that must be renewed after evaluation.
- Increase public space, improve the quality of public space, and classify open space.
- Create an independent walking system from the original traffic system and improve walking accessibility.
- Increase elderly service facilities and create elderly-friendly spaces.

- Circular construction design

- Use circular materials as much as possible in the regeneration process and consider reducing the number of materials used in the Design.
- Prioritize on-site reuse and increase the use of bio-based materials. The remaining materials are used as much as possible of recycled materials.
- Design for reversible modular construction.
- Set up collection points and community circular lab.

- Elderly adaptive design

- Use toolbox to provide space to support various elderly activities.

- Future adaptive design

- Apply a flexible grid to the public space and put the toolbox into the grids to form the public space.
- Use the changeable modules to adapt to future changes.
- Design multi-functional public space for different groups of people to share the area freely.
- Make water permeable design using sponge city and Wadi methods.
- Make an eco-friendly design by creating larger and continuous natural green space.

9

CIRCULAR CONSTRUCTION NETWORK

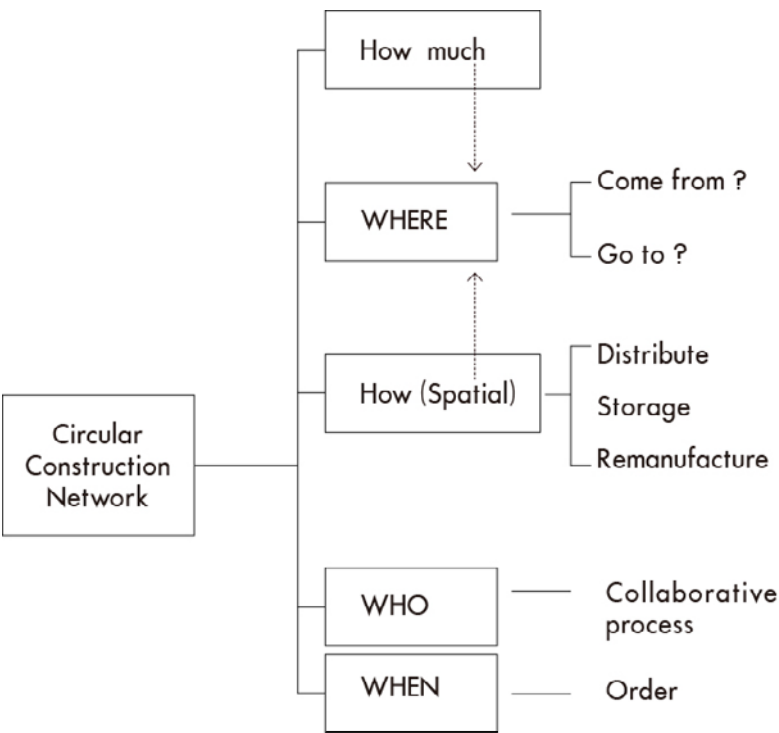


Fig. 9.1| Research structure of circular construction network

9.1 INTRODUCTION

After the previous research, we have understood how circular construction is applied to the regeneration of specific new workers' estates' public space. However, as mentioned earlier, not all materials for circular regeneration can be reused on-site. Still, most of the materials need to be recycled, relying on the help of a circular construction network under the current construction technology. At the same time, to make the research more systematic and can be applied to multi-scale practice, this chapter will specifically study what the circular construction network is and how to implement the collaborative circular construction network.

The research will focus on where is the circular materials come from and used for; the amount of material flow; how can the circular progress work (circular chain) spatially; who will be involved in the new construction way, and the timeline of circular construction network development.

The 'where' and 'how much' questions link with the concept of urban mining, to learn the supply and demand relationship of circular material flow. Then, one of the aims of the circular construction network is to match the supply and demand intelligently.

One of the reasons why the circular techniques are not widely used in urban regeneration currently is that the cost and benefit are not balanced. Therefore, there is still a need to research the possible business model to enhance the willingness of the stakeholders to use the circular construction.

Using circular material for urban regeneration will be a project that takes a long time, from planning to demolition to produce waste material, and then to renewal. This process involves many steps. The start time of these steps is different, and the time required to complete them is also different. Therefore, the timeline needs to be completed as part of guiding circular regeneration.

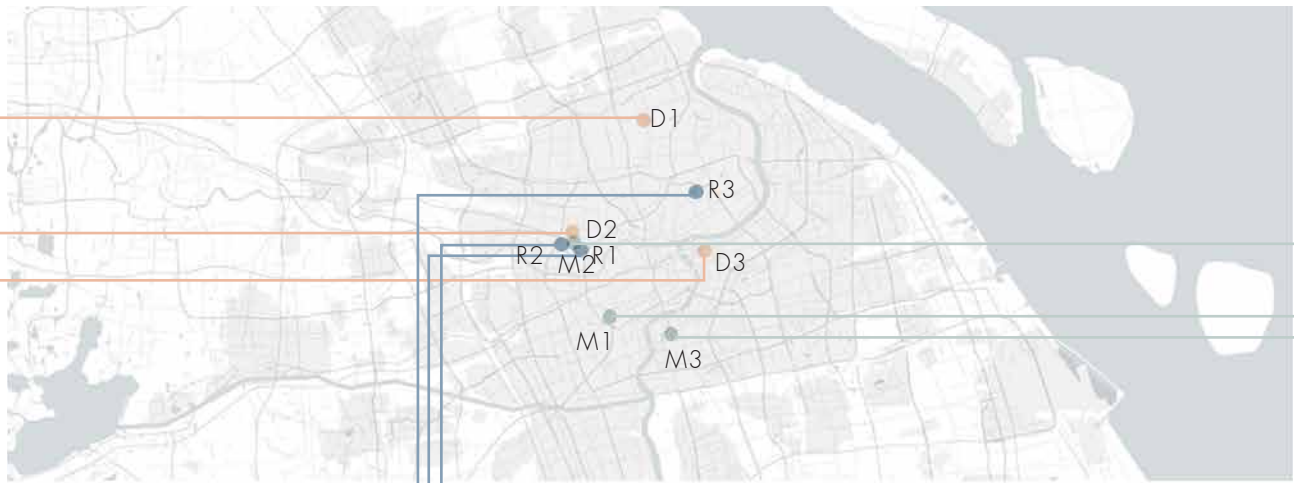


Fig. 9.2| Location of urban minings

Demolition	Refurbishment	Maintain
-Sitang New Workers' Estate -Low quality -Low value -Medium material flow -Local development as social housing	-Nanling Estate -Medium quality -Medium value -Low material flow -High willingness of residents	-Caoxi Estate -High quality -High value -High material flow -Identity of historical landmark
-8th Caoyang New Workers' Estate -Low quality -Medium value -Low material flow -Densification plan	-Youdian New Workers' Estate -Medium quality -Medium value -Medium material flow -Surrounding communities regenerated	-2th Caoyang New Workers' Estate -Medium quality -Medium value -High material flow -Future district center
-Laoshan New Workers' Estate -Medium quality -High value -Low material flow -Future city center	-Anshan New Workers' Estate -Low quality -Low value -High regeneration flow -Complex property rights issues	-Shangnan New Workers' Estate -High quality -Medium value -Medium material flow -Low willingness of residents

The regenerated new workers' estates are potential urban mining resources. The waste materials from the demolition, refurbishment, and construction of new workers' estates supply urban mining resources. Meanwhile, the demolition, refurbishment, and maintenance of new workers' estates have demands for circular materials. The supply and demand of urban mining form a circular flow and usage of the building materials.

No single site can complete the circular cycle. The circular construction network involves the cooperation of several sites with various characteristics.

9.2.1 Case study

In order to make the urban mining cases more reasonable as part of the network, choose nine representative sites all over the city with different characteristics to form the supply and demand nodes. Among them, each regeneration method has three cases. The current situation description which decides the regeneration method contains the quality, value, material flow, and other factors of the new workers' estate.

The demolition sites are always low quality and do not involves too much material flow. Generally, they follow the urban planning for densification or new functions. While, if the site has a really high value and an essential place for future development, even the quality is not relatively low, it can still be demolished for higher value redevelopment.

The refurbishment sites are always medium quality, some parts of them need to be regenerated, and the residents' wishes of regeneration are strong. Besides, when the site is so big that the whole demolition involves too much material flow and complicated process, it can be a choice to refurbish the easier and more urgently needed part.

The maintained sites should be of high quality. The sites with medium quality and medium or low quality could also be maintained due to lack of funds or residents' wishes.

Quality	Structural safety	Economy	Regeneration cost	
	Interior environment		Consumption of resources and energy	
	Equipment and facilities		Housing price	
	Unit size and independence		Land price	
	Building age		Rents	
	Facade quality	Local development	Land use plan	
	Energy consumption		Market demand	
	Public space quality		Household wishes	
	Public facilities		Property rights	

Table 9.1| Checklist of indicators

9.2.2 Decision making guideline

In addition to the nine sites that have been selected, in order to form a circular construction network covering the entire city, more sites will be evaluated in practical applications and decided which regeneration method to apply, so as to determine where the materials in the circular construction network flow out and where they flow to.

In order to complete these series of decisions, experts from different disciplines are required to collaborate. Conduct field surveys and evaluate the quality, value, ease of regeneration, and future development factors of new workers' estates. Table 9.1 lists the indicators that need to be assessed. Finally, by comparing the cost, material consumption, energy consumption, and quality improvement required by the three regeneration methods, the most suitable regeneration method for each site is decided.

9.3 CURRENT MATERIAL FLOW

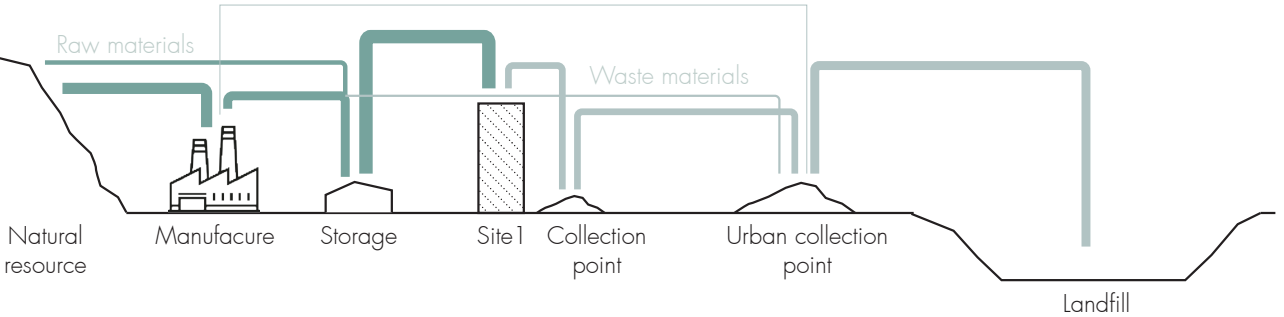


Fig. 9.3| Section of linear material flow

9.3.1 Linear construction material and waste flow

The construction materials consumed during the linear regeneration process are extracted from natural resources, directly stored, or processed by the factory, then centralized storage, and finally distributed to the site through logistics. A certain amount of production waste is also generated during the processing of the construction material factory (Fig. 9.3). The CDDW generated during the building regeneration process is first distributed to the nearby collection point and then gathered to the city's collection point. After a simple separation, most of the waste is sent to the landfill area for infill. Only about 5% of the waste can be reused (excluding construction mud) and entered the factory for reprocessing. Part of the construction mud will fill the foundation of other sites.

In general, the current material flow is almost linear flow, and the resource utilization rate for CDDW is very low. The reuse of the CDDW is also down cycle reuse, and the value of construction waste is not fully utilized. In detail, as shown in Fig. 9.4, different materials have alternative flow processes.

In detail, as shown in Fig.9.4, different materials have alternative flow processes. Natural raw materials are extracted from the natural environment. Some materials like sand and stones can be directly used in construction are distributed to market and construction sites. Other kinds of materials are processed in manufactories and then distributed to market and construction sites. The retail markets mainly serve retail customers for decoration. Developers stock only a small proportion of them.

The waste materials from the demolition, construction, and decoration process of new workers' estates are collected by waste distribution to landfill. However, landfill treatment in the natural environment cannot be revived to new materials in a short period. It means the chain is ruptured at this step. The waste can not make new values, while the raw materials are irreversibly mined from the natural environment.

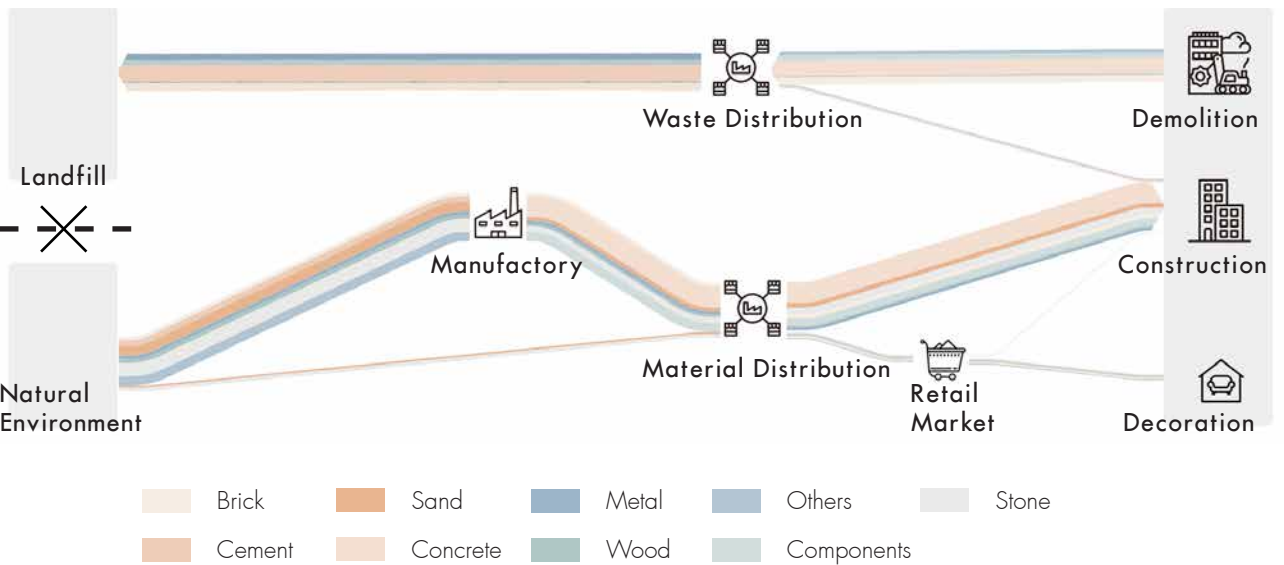


Fig. 9.4| Linear material chain and flow



Fig. 9.5| Current infrastructure and material flow

9.3.2 Existing infrastructure and flow

If the nine sites are regenerated under the current linear construction, the material flows could be as shown in Fig. 9.5.

The small dots show the location of existing building material industries, such as brick, cement, concrete, rebar, and wood. These spots get raw materials from natural sub-urban areas or from outside the city. The raw materials are distributed to the storage, and the construction products are also distributed to the nearest warehouses. Then the materials and products are used to the regeneration of the new workers' estates.

The waste materials generated by the regeneration of new workers' estates are distributed to the nearby collection points and then poured into the landfill sites in the countryside. Shanghai has the following goals in dealing with CDDW. First, strengthen the management of the declaration of various types of construction waste at the source, especially to implement the full statement of decoration waste and demolition waste, and improve the management. Secondly, establish a transit separation system. Thirdly, strengthen the supervision of transportation enterprises' collection and transportation behaviors; Fourthly, implement territorial consumption selection, and create local emergency disposal sites; Fifthly, prevent illegal dumping of CDDW. (Liu Jingjing, 2016)

After construction waste is not allowed to be distributed to other cities, the CDDW is disposed inside Shanghai. The construction mud in the central area of the city is first backfilled in the central districts, and the remaining waste will be sent to other districts for treatment. The waste produced in the suburbs is backfilled inside the area.

The existing infrastructure map shows the basic construction system and transportation system, which is also the most influenced and potential area for future circular development.

- Demolition sites
- Refurbishment sites
- Maintenance sites
- Brick industry
- Rebar industry
- Cement industry
- Concrete industry
- Wood industry
- Storage
- Waste collection
- Material markets
- Raw material flow
- Waste material flow

9.4 CIRCULAR MATERIAL FLOW

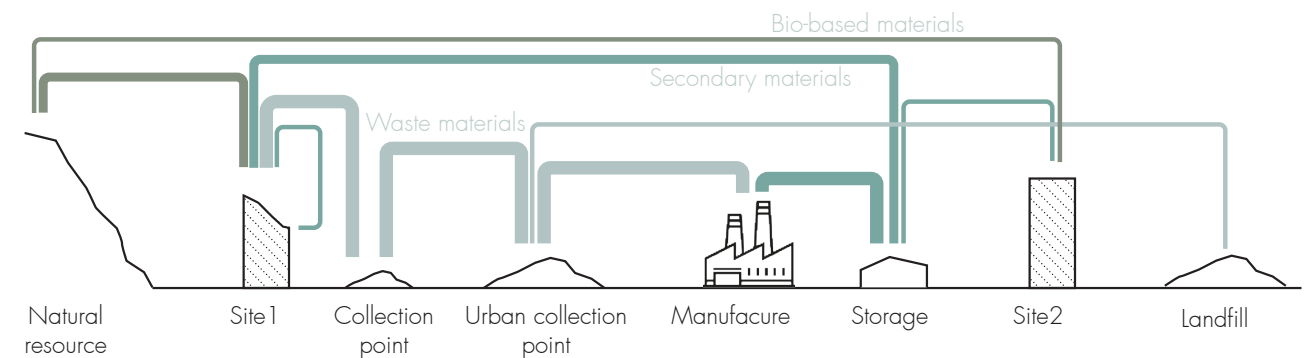


Fig. 9.6| Section of circular material flow

9.4.1 Circular construction material and waste flow

The circular construction takes the built urban area as urban mining. As shown in Fig.9.6, the waste materials from site 1 can be on-site reused or be recycled after collection, separation, and remanufacture and then be circularly used to site 1 or other sites. During the new construction, use the bio-based materials and prefabricated modular products to reduce future recycle costs. By this circular construction method, both the waste material flows to landfill and the material extracted from the natural environment have an apparent decrease. The waste materials regain value.

In detail, as shown in Fig.9.7, although there is still no rapid conversion between landfill and natural environment, the tran-

sition node becomes the 'remanufacture,' and the conversion speed is greatly improved here, thus forming a cycle.

The waste generated from the regeneration process like wood and bricks can be on-site reused for new construction. Most of the waste is collected, separated, and distributed to remanufactures for recycling. In order to build a long-term sustainable and circular construction, more recycled materials are prefabricated into products (components and modules) for new construction. Unlike linear flow, more bio-based materials are specially planted and also prefabricated into easy to reuse products.

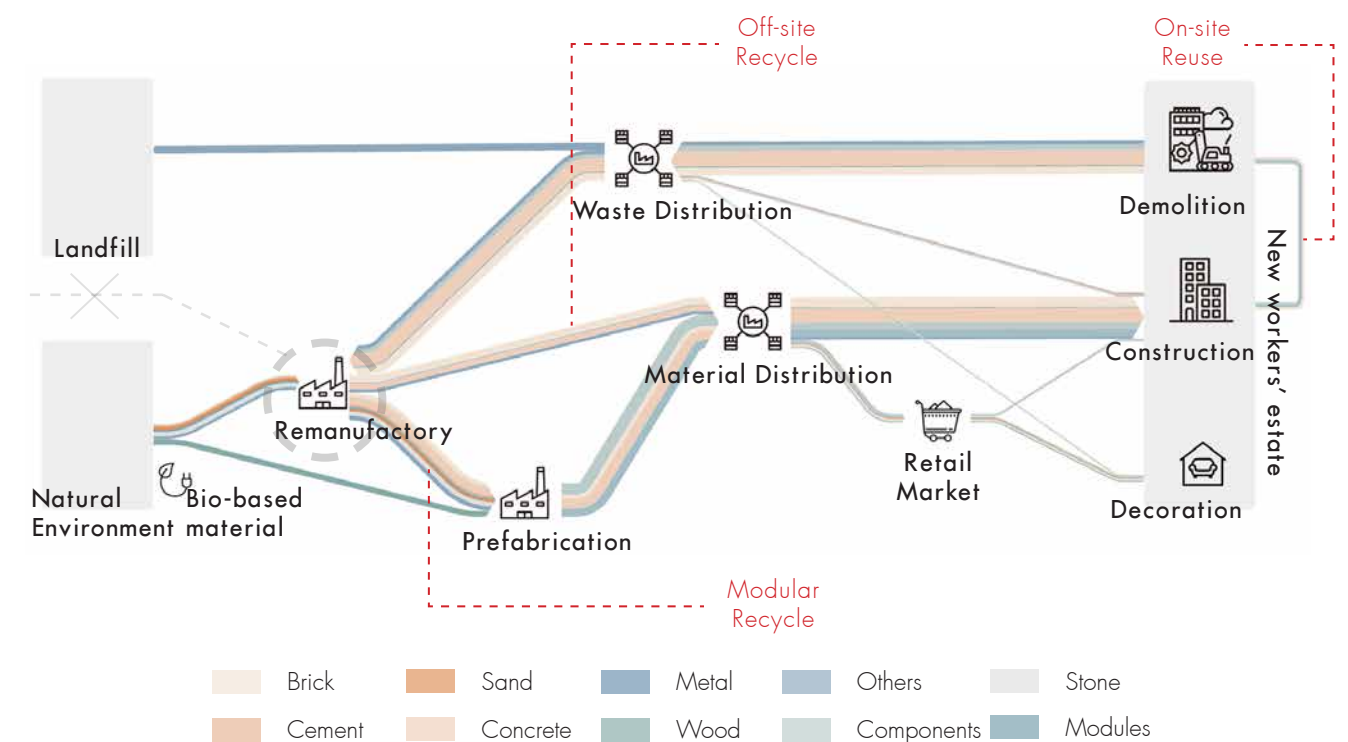


Fig. 9.7| Circular material chain and flow

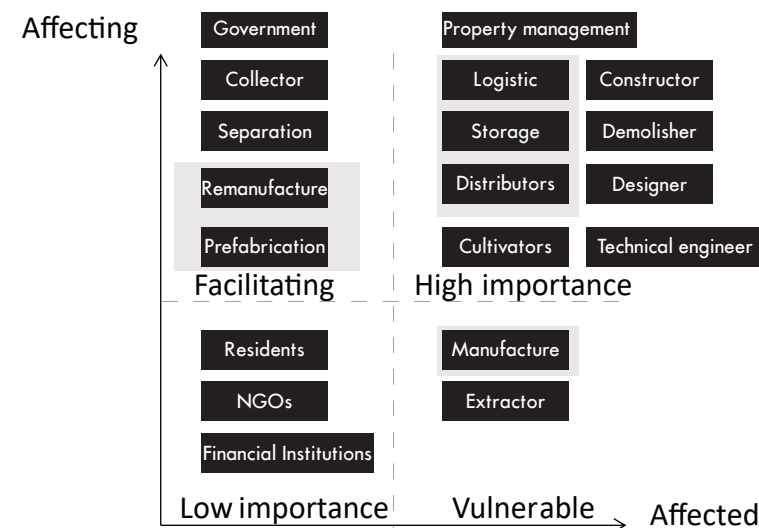


Fig. 9.8| Changing situation of stakeholders

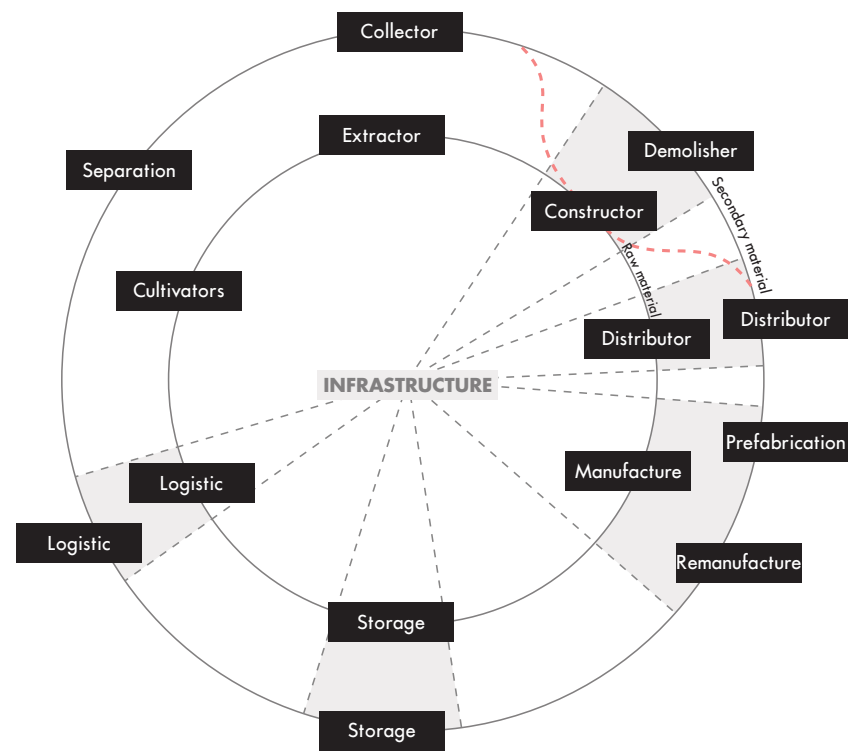


Fig. 9.9| Potential of sharing infrastructure

9.4.2 Transformation of existing infrastructure

During this transition from linear construction to circular construction, many nodes on the value chain and stakeholders are affected and affecting, as shown in Fig.9.8. The manufacturing process will be significantly affected due to the decreased amount of material consumption. On the other hand, the remanufacture and prefabrication process are new industries that are affecting the circular construction. In general, these three processes can share similar facilities and infrastructure for production.

The logistic, storage, and distributors are both profoundly affected and affecting in this transformation. The process of dealing with the raw materials and circular materials can share the

same facilities and infrastructure. The affected output of these processes can be fetched up by the new circular demands.

Therefore, link these processes into the spatial analysis, as shown in Fig.9.9. These grey nodes in the two industry chains have the potential to coincide, which means that they can share infrastructure. Following the principle of circular construction-reducing the unnecessary construction, reduce the new development of industrial facilities and infrastructure on the circular industrial chain, but transform the old infrastructure with low capacity to form the industrial part of the new circular construction network.

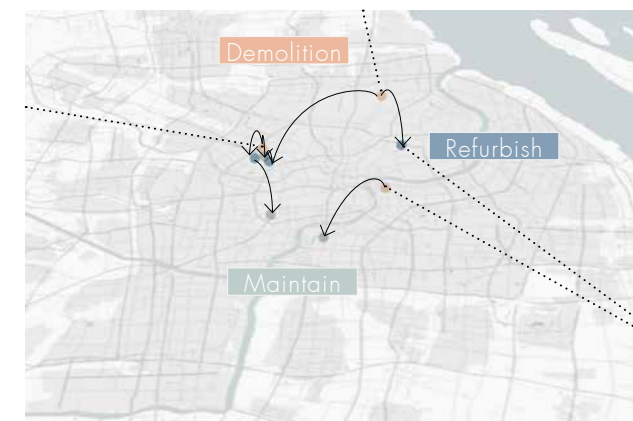


Fig. 9.10| Urban mining and material flow

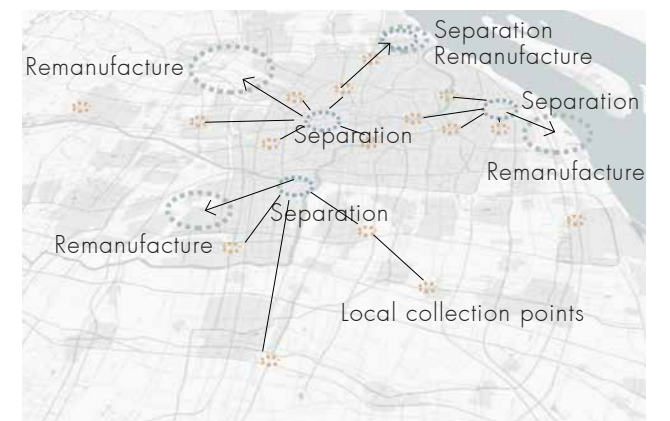


Fig. 9.11| Circular material flow in semi-public space

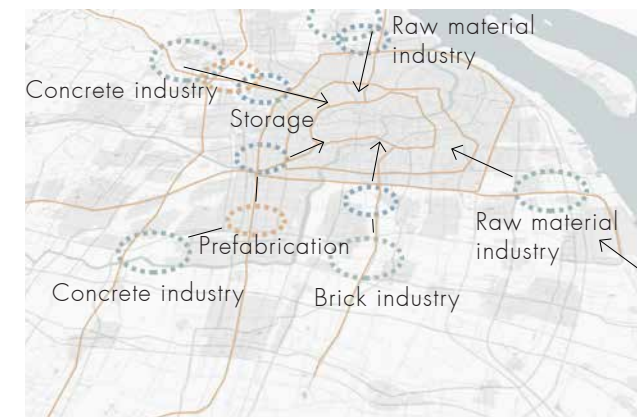


Fig. 9.12| Circular material flow in semi-public space

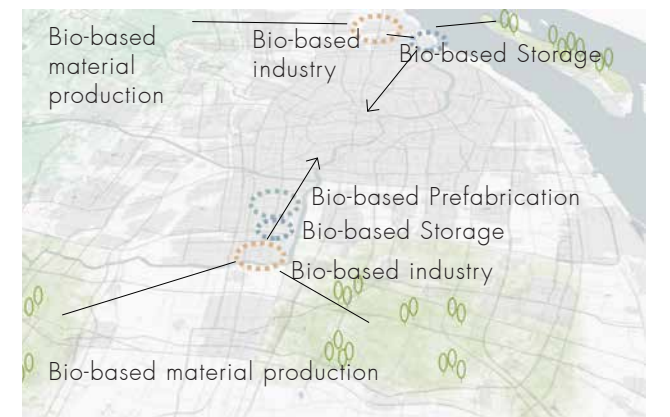


Fig. 9.13| Circular material flow in semi-public space

The transitional process is shown as follows in four steps.

Urban mining and material flow

The chosen sites act as urban mining where waste materials flow out and flow to, which is the supply and demand of the circular construction network (Fig.9.10). The material flows among them from demolition sites to refurbishment and maintenance sites, and from refurbishment sites to maintenance sites. Meanwhile, there are still materials from the natural environment and flow back to the natural environment.

Collection and separation treatment

Waste collection and separation is the first step in waste treatment and the basis of circular use of CDDV. The separation of CDDV includes two types. The first type is simple preliminary separation, which classifies different types of waste roughly. The second type of separation is more intensive, which separates the waste materials into raw materials that can be reused, which is the direction of development. In recent years, Shanghai has tried to introduce machines in the central area for automatic sorting.

There should be treatment spots in hierarchies, which deal with the waste in different scales, as shown in Fig.9.11. After the collection and separation, the materials are distributed to the remanufactories for a new life.

Industrial nodes

Based on the existing industrial infrastructure, according to the functional configuration, location, and development plan of each industrial zone, summarize their main functions in the circular construction network in the future.

There are industrial nodes mainly for concrete industry, prefabrication, brick industry, and other raw materials industries. The products are distributed to the storage and the construction sites through existing freight infrastructure.

Bio-based materials

The bio-based material productive areas are located in the south part, north-west



Fig. 9.14| Nodes in circular construction network

part, and Changxing Island. These areas have a potential or plan for wood growing and other bio-based materials planting. The bio-based materials are processed and prefabricated in the nearby bio-based industry.

9.4.3 Nodes in circular construction network

In conclusion, there are several nodes fixed in the circular construction network.

The regenerated new workers' estates are located inside the outer ring road, using demolition, refurbishment and maintain regeneration methods.

Together with the waste collection, remanufacture, concrete industry, other raw material industry, bio-based industry, prefabrication, and storage, they form the essential nodes of the network. According to the function combination, there are some clusters of nodes with similar locations. They form industry cores for multi-functions.

The east core has the function of the traditional raw material industry. The north core, which locates near the productive area of bio-based materials and the biggest and the most varied raw material industry, acts as the raw material and bio-based industry core. The north-west core, with the most prominent waste treatment amount and concrete industry, serves as the remanufacture center. The south-west core, with the facilities of prefabrication, bio-based material industry, and other kinds of raw material industry, is the bio-based, remanufacture, and prefabrication center of the city.

The materials handled by these cores are different. They have the same function to serve different areas of the city. They also have their own unique functions to provide new facilities and services for future circular development. Therefore, these important nodes serve as the basis for forming a network.

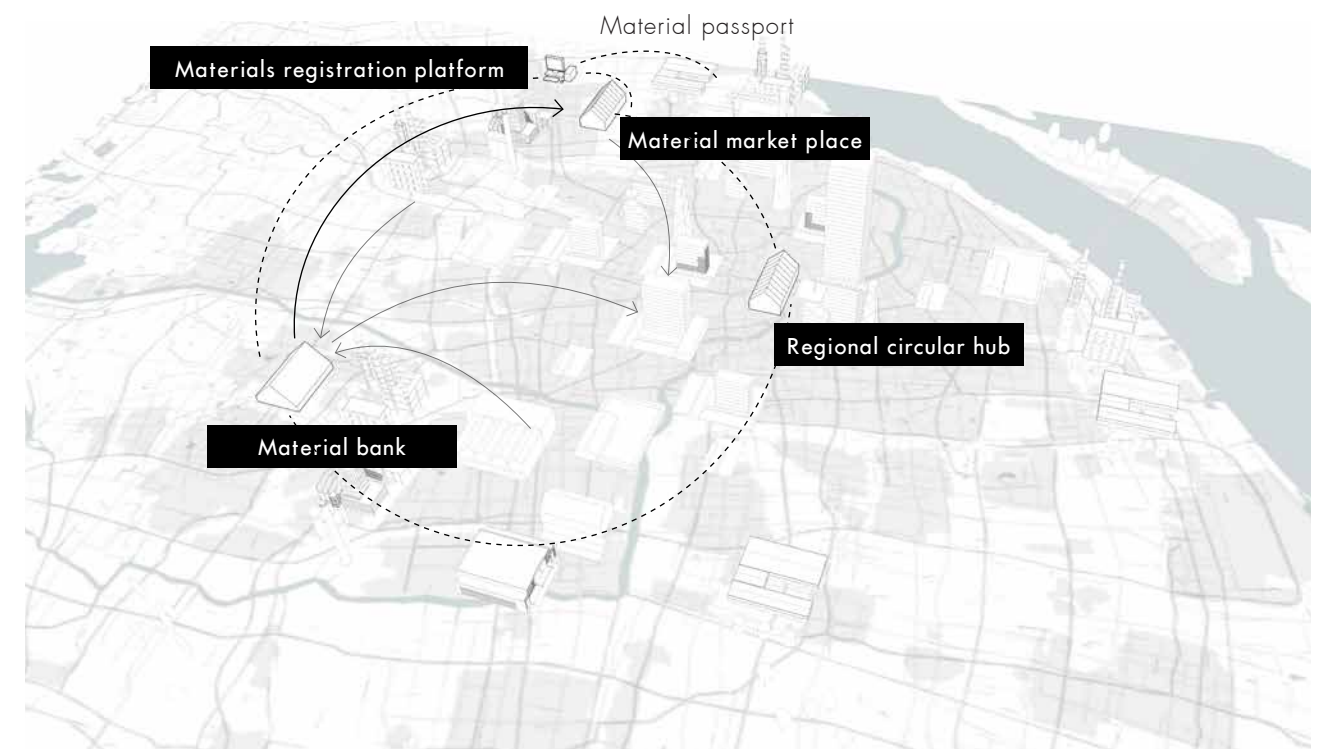


Fig. 9.15| Circular material supply and demand matching system

9.5 SUPPLY AND DEMAND MATCH

By knowing the supply and demand, and how can the materials flow among them, there should be some methods to match the supply and demand so that the circular construction is efficient. The tools for supply and demand matching are listed.

— Physical material flow
 Material data flow

- Material passport (BIM)

It is information of sets of data describing defined characteristics of materials in products that give them value for recovery and reuse (Matthias Heinrich, Werner Lang, 2019).

- Material bank

A material resource library, a platform and storage area for circular building materials.

- Material marketplace

Physical marketplace, supply and demand of building materials for construction

- Material registration platform

Online database platform for construction waste and materials through Gis database (Zhu, 2014).

- Knowledge sharing hub

The center of the network and data sharing platform can also be a real place for trading headquarter and stakeholders meeting as a knowledge hub.

These tools are located in the city spatially, as shown in Fig.9.15. The material bank, material marketplace, and knowledge sharing hub have physical locations near the essential industry nodes. The material registration platform is an online platform, and the data flow covers all these spots based on the material passport. Through these online and offline platforms, the waste and materials generated from the sites and the industrial nodes are integrated, and the optimal solution is calculated and applied.

9.6 COLLABORATIVE NETWORK

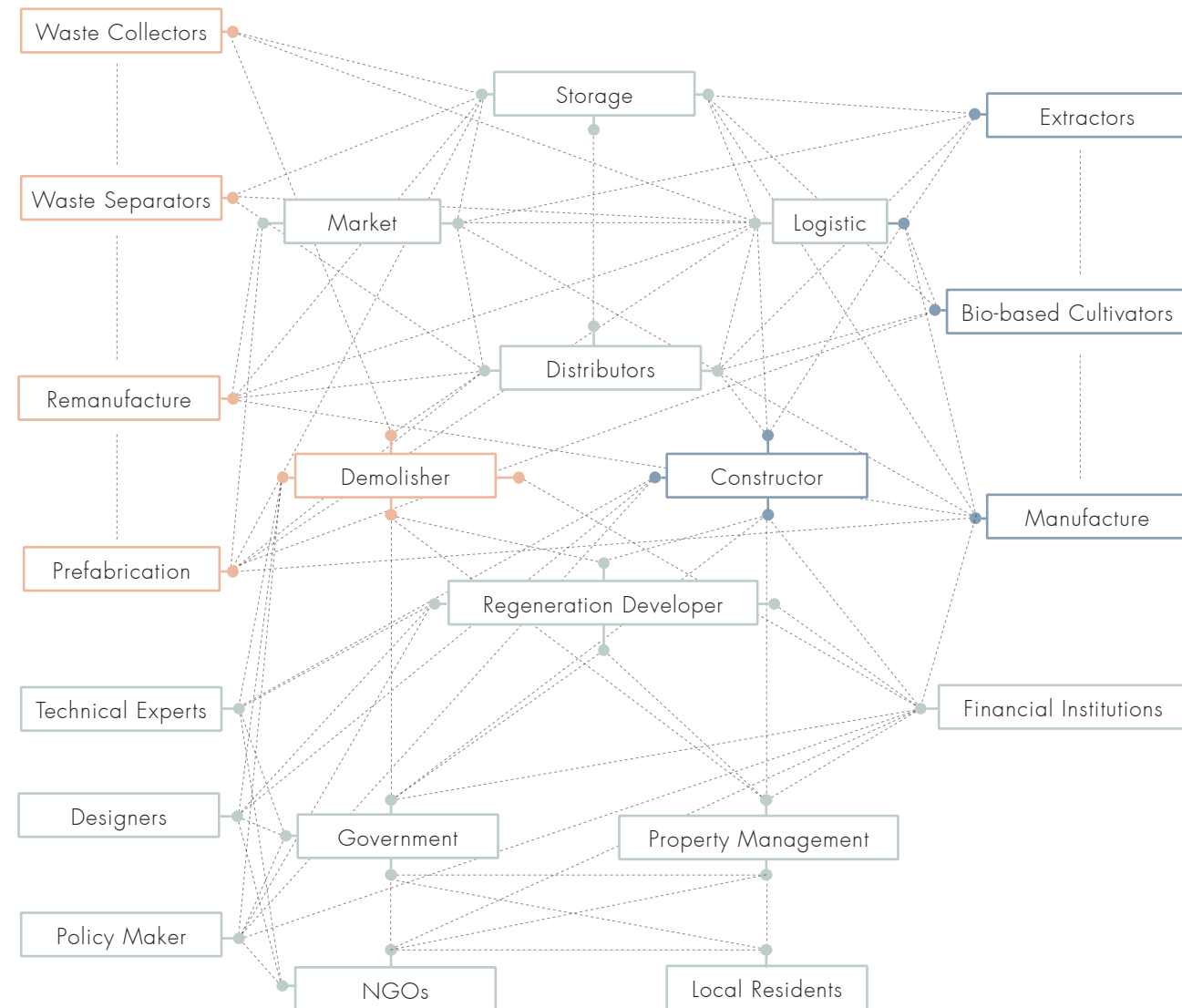


Fig. 9.16| Collaborative stakeholder network

9.6.1 Collaborative stakeholder network

In order to make the supply and demand matching system works well, there is a need for a collaborative process among the stakeholders.

The process towards forming a circular construction firstly requires each stakeholder to contribute knowledge and create a consensus (Fryslan et.al., 2017). In addition to the two types of stakeholders that are affected and affecting the most (raw sector and new sector), those who cover both sectors are also important. There is a need to consider the wishes of everyone and respond to the economic and social issues involved in the entire process. In the end, the method with the least waste, the least energy consumption, the highest financial benefit, and the maximum solution to social problems forms the circular construction network.

The data supporting the database needs to be provided by different stakeholders. In this way, the statistics of materials supply and demand from all locations and stakeholders are open and transparent. Stakeholders use the Internet platform to build a complete set of production collaboration relationships and form a rich and diverse business ecosystem through free and open business cooperation.

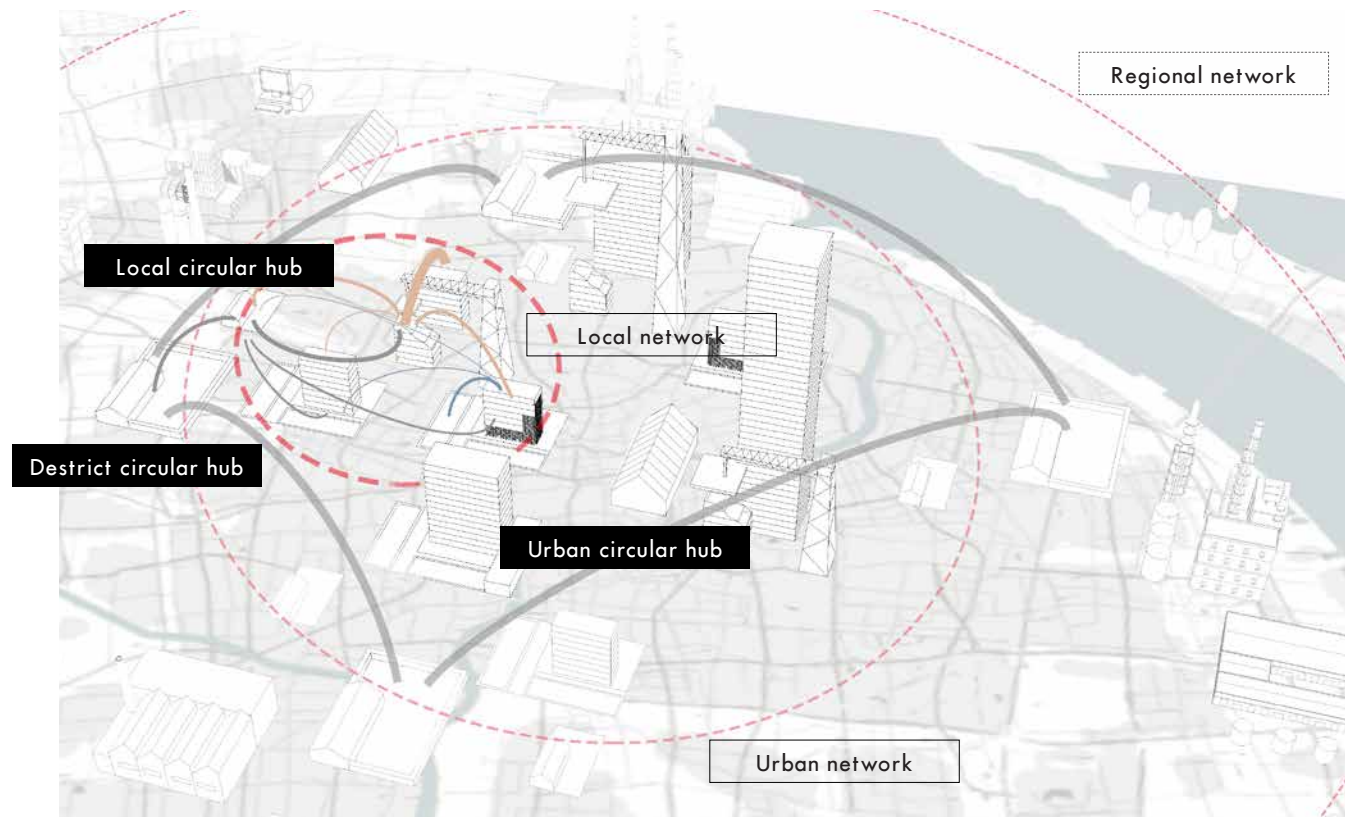


Fig. 9.17| Collaborative scale network

9.6.2 Collaborative scale network

No single site can achieve a complete circular construction, and a feasible circular construction network must be the result of the collaboration between multiple sites and multiple scales, as shown in Fig.9.17.

Following the principle of reducing energy consumption, long-distance transportation of waste and materials should be avoided as much as possible. Therefore, when more waste can be generated on-site reuse than the site itself needs, local redistribution is preferred. The waste that needs to be reprocessed because it cannot be directly reused is transported to the nearest processing node for recycling.

If there are still materials and waste supply that cannot be fully used in local areas or material demand that cannot be provided in local areas, it is necessary to coordinate in the entire urban area or even the regional area. The local network is mainly for materials that can be directly reused, and it is difficult to include reprocessed industries in urban areas. Most of the waste that needs to be reprocessed through the material industry needs to cooperate with the urban network to complete the entire circular chain.

Each district browses through the data to find synergies for themselves, but the method and framework of cooperation in various regions should be unified. The data should be registered on the regional material platform. So that under the same framework, it is possible to manage the extra supply and demand with the cooperation of other districts. Therefore, the urban network and local network can cooperate.

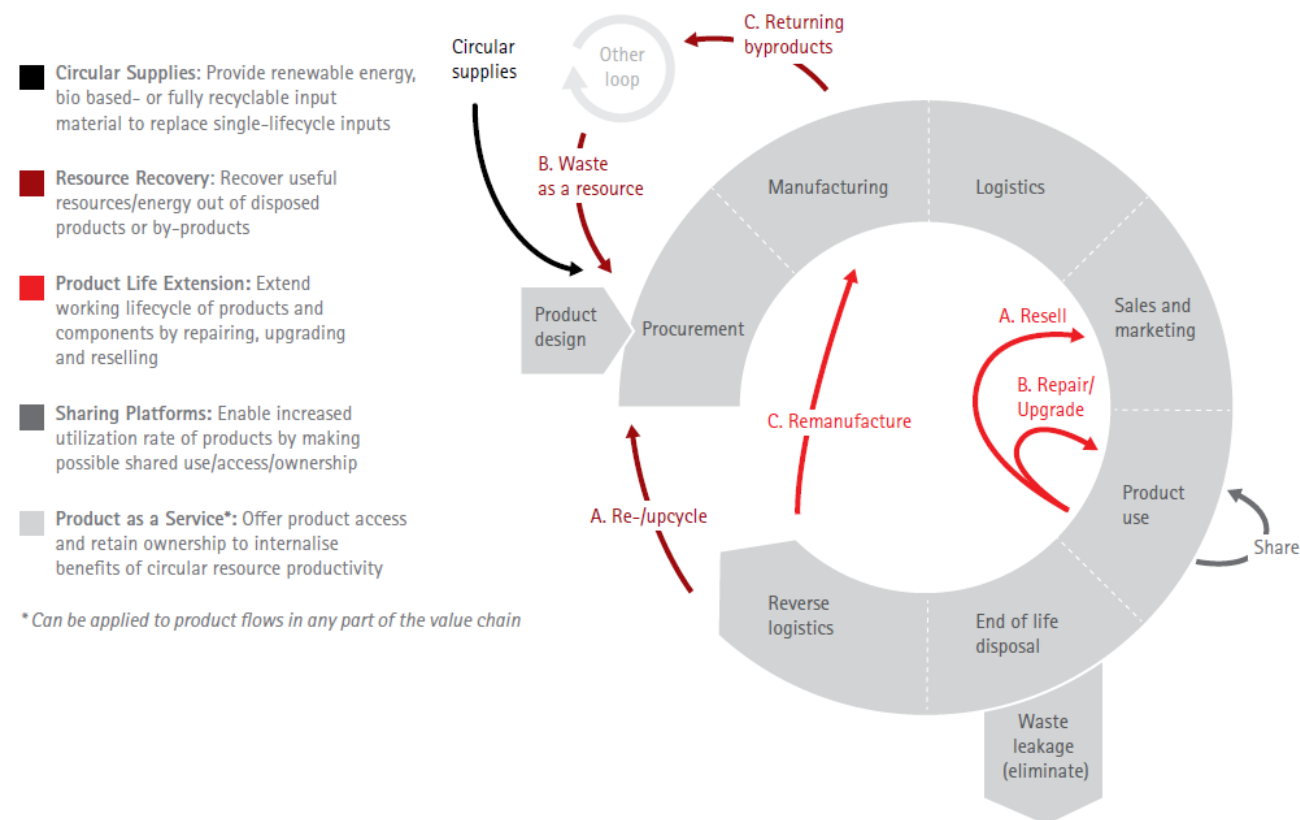


Fig. 9.18| Accenture classification of circular business models (Lacy, 2014)

9.6.3 Business models

The collaborative network of the new circular construction chain needs business models for each stakeholder and sector. The business models are generated by the Accenture and have been reflected and applied to some circular projects (Eva Guld-mann, 2017), as shown in Fig.9.18.

The circular supplies business model is aiming to use fully renewable, recyclable, or bio-based resources instead of scarce resources. It could apply to new material production, prefactory, and bio-based industry.

The resource recovery business model takes the intrinsic value at the end of the product's life cycle and transform it into another product through innovative recycling and upgrade services. This model is based on the next generation of recycling by using new technologies, which can be applied to the remanufactories with waste material from products.

The product life extension business model is concerned with extending the lifecycle of products by repairing, maintaining, and remanufacturing of broken products and decaying urban areas. This model can be applied to the redevelopers and remanufactories.

The sharing platforms business model encourages collaboration among different product producers, consumers, and users. Those remanufacture producers with a small production scale will rely on this business model. The government can also use it for management and overall planning.

The product as a service business model means the stakeholder is responsible for the entire life cycle of the manufactured product. They provide their products through the lease. Users can use product services instead of purchasing products. This model is very suitable for modular construction. The prefabrication owners of modules can provide pay-for-use service to the regeneration sites. When the modules are not suitable for future changes, the owners can easily dismantle them from the sites and apply them to other areas. By this business model, it drives the stakeholders to improve the durability and upgradability of their products.

The application of the business model is also combined in Fig.9.20.

9.7 ROADMAP

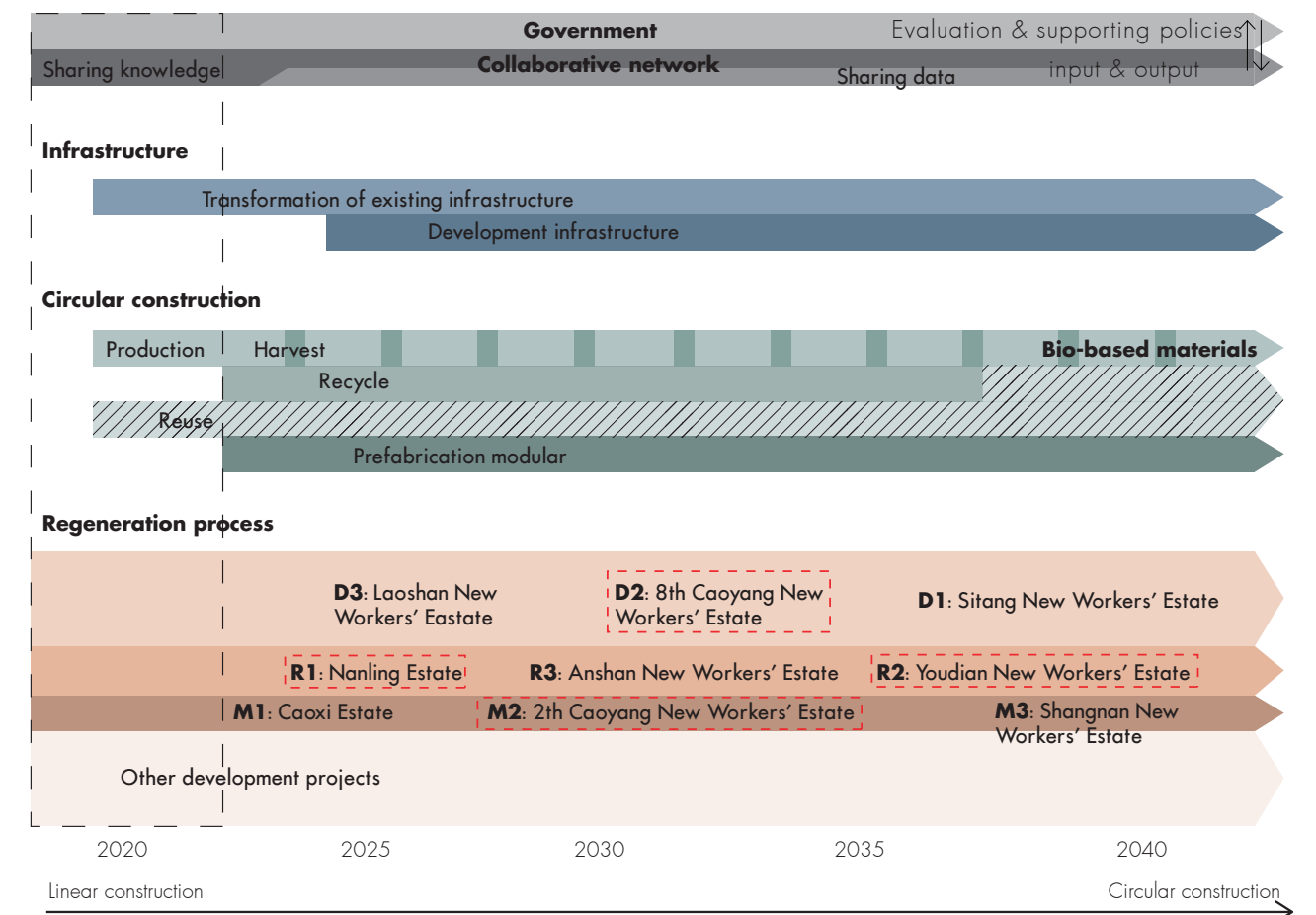


Fig. 9.19| Timeline of circular construction network development

As different industries and new workers estates have different levels of development, various steps need to be taken to achieve circular construction, and the start time and the time required for changes are also different. Therefore, a roadmap is required to plan the overall development timeline, see in Fig.9.19.

This is all related to evaluation moments and input from stakeholders and experts throughout the process. Project groups can be supported by the circular construction network focusing on the establishment of circular developments. On a government level input from both the project groups and the circular construction network can support evaluation moment and supporting policies.

The infrastructure development first starts with the transformation of the existing facilities, and then develop more necessary ones. For circular construction, planning and preparation of bio-based materials will start earlier and requires a longer growth cycle. Subsequently, the technically simpler reuse is started first. With the development of infrastructure and the completion of the technology, recycling and prefabrication are gradually started. Hopefully, in the end, materials that can be reused can replace the elements that cannot be reused directly.

The regeneration development projects also have a chronological sequence, based on the quality of the status quo, the needs of urban development, the needs of residents, and other factors. Although some projects are located in one local circular network, they have different construction times and cannot share materials at the same time.

Over time, the circular technology is more advanced, the development of the circular construction network is also more systematic, so the circular regeneration of the projects will become more scientific and efficient.

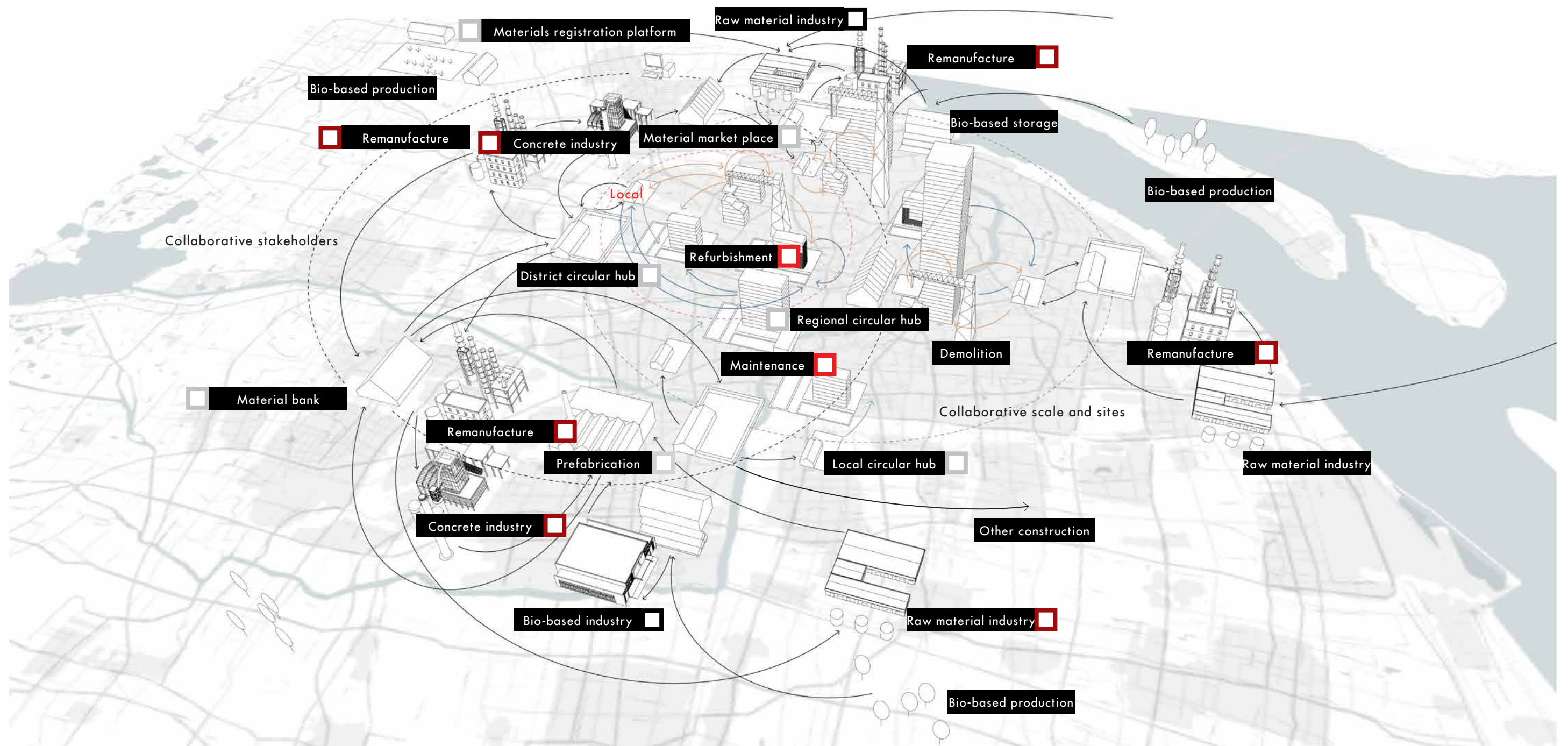


Fig. 9.20| Conclusion map of circular construction network
(Legends as shown in Fig.9.18)

9.8 CONCLUSION: CIRCULAR CONSTRUCTION NETWORK

- Urban mining- supply and demand

The demolition sites primarily supply waste materials and demand for circular materials. The refurbishment sites also provide waste materials and demand for circular materials. The maintenance sites have demand for circular materials.

- Transformation of infrastructure

Prioritize transformation of existing infrastructure for the development of circular construction networks.

- Supply and demand match

Use the tools of material passport (BIM), material bank, material marketplace, material registration platform, and knowledge sharing hubs to achieve an accurate and efficient match between supply and demand.

- Collaborative network

Form a collaborative network from the two aspects of stakeholders and cross-scale (sites). Sharing knowledge and data among different stakeholders in different steps to create the network and to drive the collaborative network. Also, sharing the infrastructure and material data on the local scale, urban scale, and regional scale.

- Business model

Find a suitable business model for each sector on the circular construction chain. The circular supplies model is fit for circular industries; the resource recovery model can be used by remanufactures; the product life extension model suits the redevelopers; both producers and managers can use the sharing platform model; the product as a service model is suitable for modular construction.

- Timeline

From the perspective of government management, infrastructure transformation and development, the implementation of circular construction methods, and the timing sequence of the regeneration projects, the development of the circular construction network needs to be progressive.

10 CONCLUSION

The main research question of this thesis project is **“How can the CDDW generated during the regeneration of new workers’ estate be circularly used to make the public space more sustainable and adaptive to future changes?”**. In order to answer this question, 5 sub-questions were put forward:

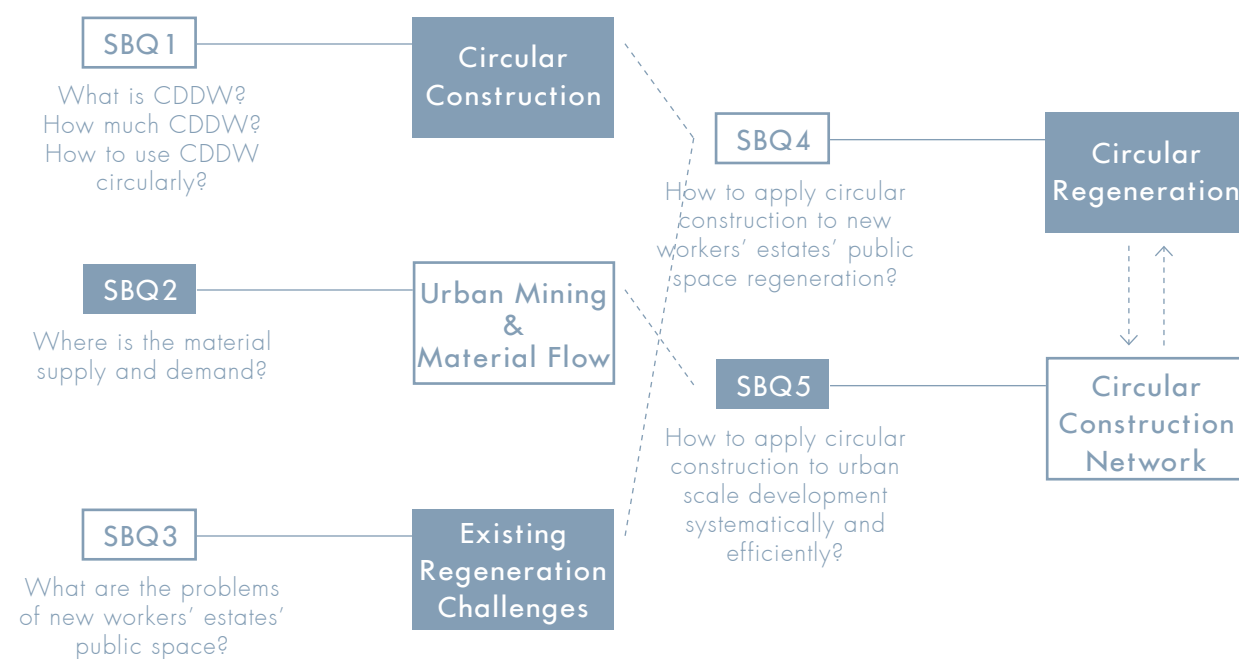
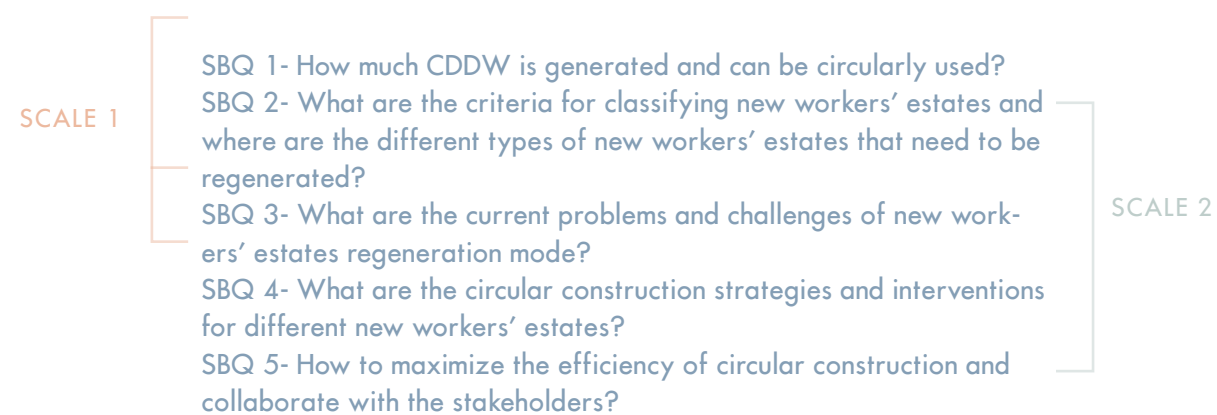


Fig. 10.1 | Thesis structure based on sub-research questions

- Circular construction

· A large amount of CDDW generated during the regeneration process, and a large amount of material is also required. Based on the developed circular construction technology, these CDDWs have the potential to be circularly used in new regeneration construction, thereby making the renovation process more sustainable and environmentally friendly.

· Through research and study of existing circular construction techniques, based on the strength characteristics of secondary materials and users’ acceptance, the current stage of circular construction is more suitable for application in public spaces.

· The CDDW is divided into three categories: aggregate, component, and modules. First, follow the reduction strategy.

- +Part of aggregates can be directly on-site reused, and the others need to be separated, crushed, and reprocessed into new materials. They are mainly used in public space base and structure layers.
- +The component is mainly reused after maintenance and is mainly used in public space buildings, structures, and furniture layers.
- +Modules can be reused as modular housing in the public space as a public building through a special dismantling process.

· On-site reuse saves transportation and reprocessing processes compared to recycle, so it is a more sustainable regeneration method in the long run. However, due to the current construction method, only a small part of the material can be directly on-site reuse. Therefore, in the regeneration design process, use reversible designs that are easier to reuse, such as modular designs. In this case, the materials of the future public space can be directly reused on-site or other public spaces based on the same modulus. As a result, sustainable regeneration can be achieved over a longer period of time.

- Existing regeneration challenges

· Public space quality

Existing regeneration to new workers’ estates are mainly focused on buildings, and there are fewer updates to public space. The quality of public spaces of new workers’ estates is generally low. The low quality of public spaces is reflected in the following aspects:

- + Lack of public space
- + Low quality of public space
- + Homogenization of public space
- + Chaotic walking and vehicle organization
- + Low usage of public space
- + Poor management of public space

· Aging problem

· Climate change

- After the above research, respond to the main research question and make the following vision:

Apply the circular construction network to help make circular use of CDDW generated during regeneration of new workers' estate for the improvement of elderly-friendly public space quality to make the public space more sustainable and adaptive to future changes.

- Circular regeneration

This answer the question of how to apply circular construction to public space regeneration of new workers' estates in a neighbourhood scale.

· Using the strategies for general spatial regeneration design following the principles.

· Circular construction design

· Elderly adaptive design

· Future adaptive design

- Urban mining: supply and demand

· Divide new workers' estates regeneration into three categories: Demolition, Refurbishment, and Maintain. The demolition and refurbishment regeneration supply CDDW during the regeneration and also demand circular materials. The maintain regeneration demands circular materials.

· Select a few representative new workers' estates by cases and decide their most suitable regeneration method. Take this as an example, map the material flow among them.

· Give guidance on how to give an overall regeneration suggestion on the urban scale for other cases.

· Supply and demand match through material passport (BIM), material bank, material marketplace, material registration platform, and knowledge sharing hubs

- Circular construction network

· Transformation of existing infrastructure

· Collaborative network

+ Collaborative stakeholder network

+ Collaborative sites (cross-scales)

- In conclusion, the CDDW generated during the regeneration of new workers' estate are circularly used to make the public space more sustainable and adaptive to future changes in both neighbourhood scale and urban scale, as shown in Fig.10.1.

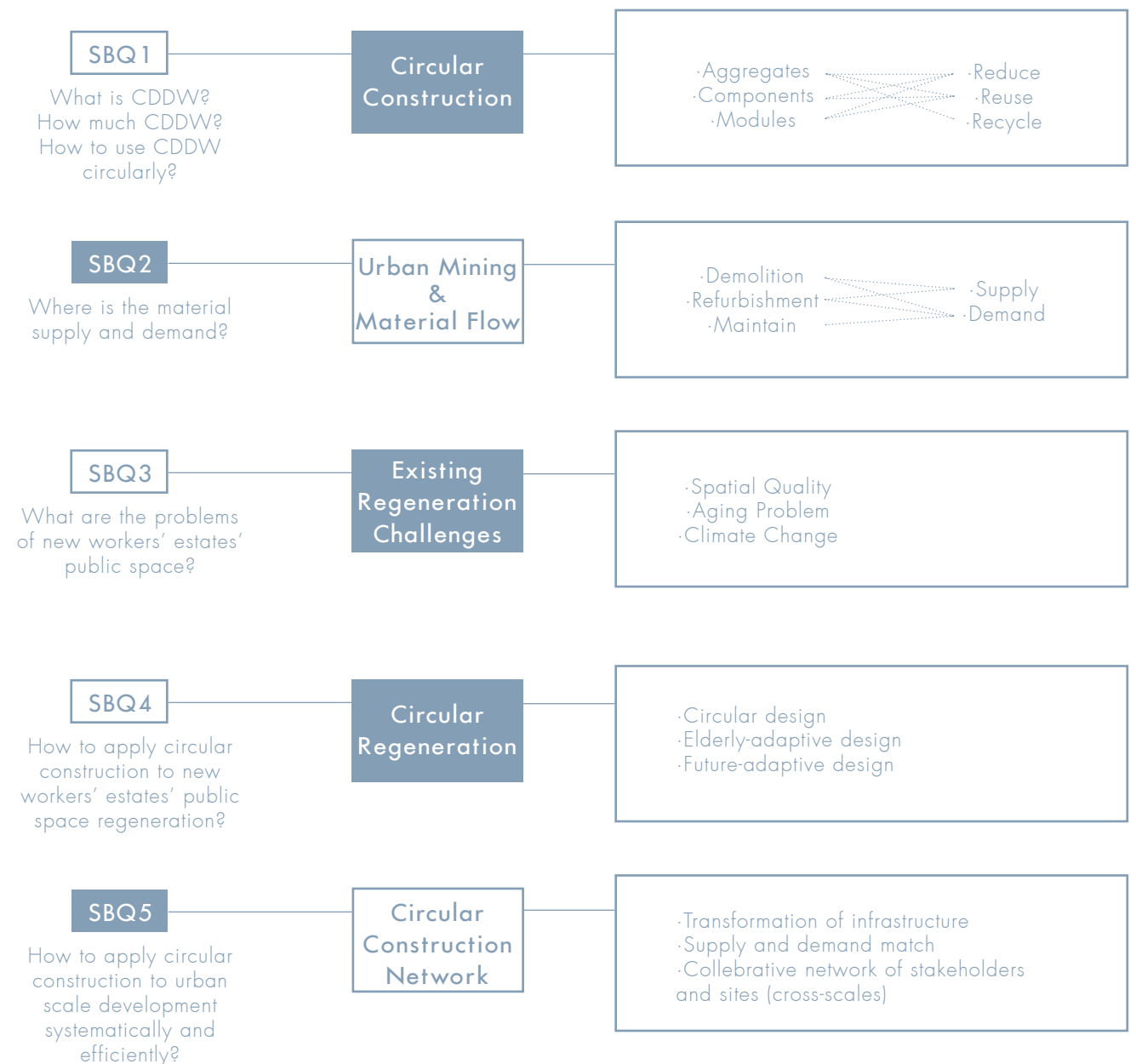
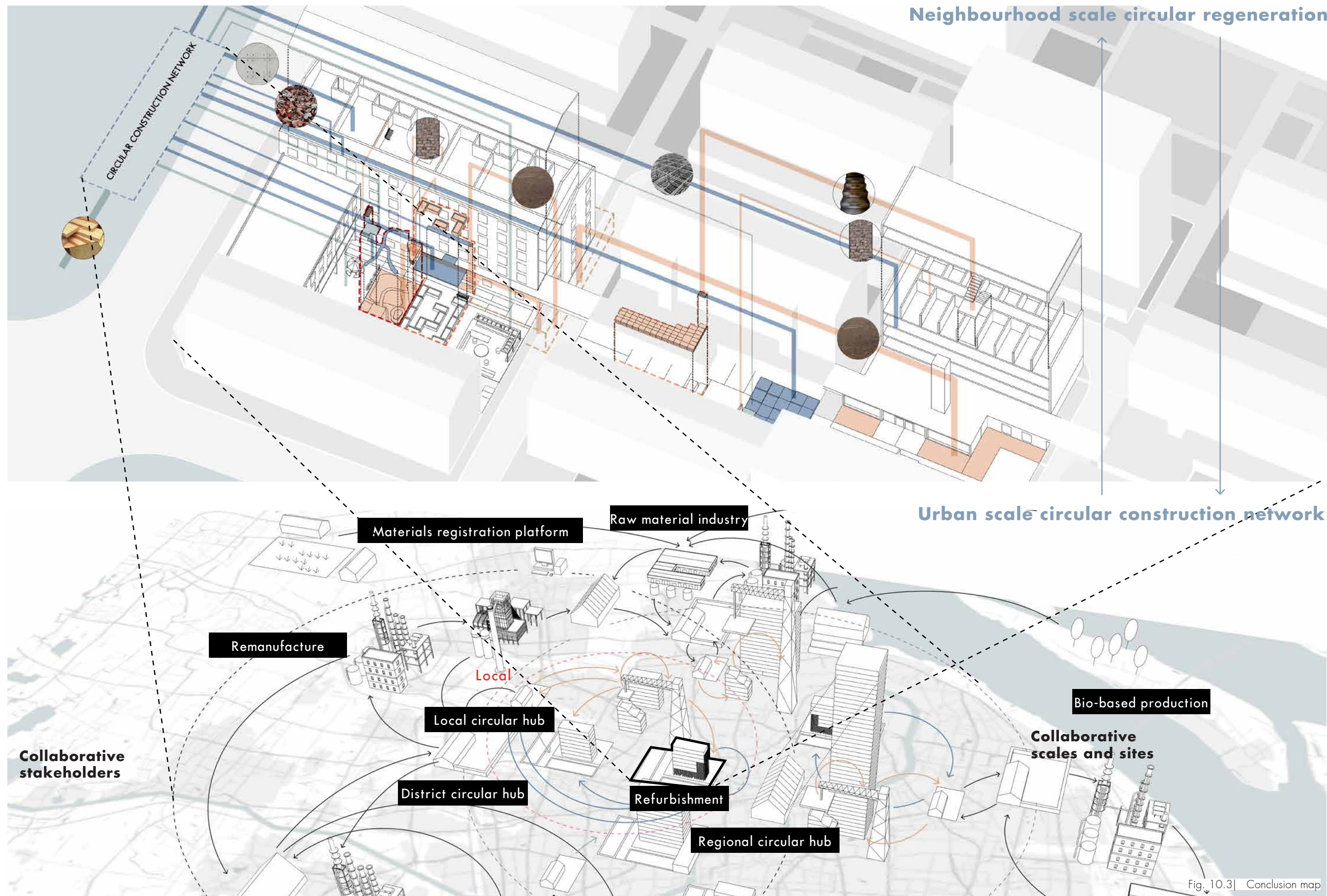


Fig. 10.2| Conclusion summary



11 REFLECTION

1.RELEVANCE

Scientific relevance

Researches on the recycling of waste building materials have been studied for a long time, and there are many related research results, but these studies have not yet been able to be applied widely. And there are fewer projects that involve these materials to the regeneration of public spaces. Due to the current techniques of recycling, building materials cannot yet use a large number of secondary materials, so using secondary materials to regenerate public spaces and build sustainable public spaces has great potential.

The waste materials generated by the building demolition and the materials required for the construction of public spaces are listed separately, and the reusability of various materials is studied, so as to select building materials that can be recycled for public space regeneration. Besides, learn the amount of waste materials that can be applied in the production process of recycled materials.

Use flexible grid and modular design to regenerate public spaces to form flexible, sustainable public spaces to face future changes. Combining these modules with sponge city technology allows them to have flexibility in adapting to climate changes and responding to natural disasters caused by rain. Study how to rely on existing urban waste management facilities to form a collaborative circular construction network.

Societal relevance

The new workers' estate is a type of residential area with Chinese characteristics. This type of residential area, which was built in the 1950s-1990s, still accounts for a large proportion of Shanghai's residential areas. However, after nearly 30-70 years of development, the quality of building and public spaces of most new workers' estates are running down, and a large number of social problems have arisen. Due to property rights, it is difficult to regenerate. In this research, the new workers' estate was selected as the research object to regenerate the urban area with low living quality while maintaining the identity and urban context inheritance of such a particular type of housing.

In addition to the renewal of buildings, the regeneration of public space is relatively significant. People are now pursuing the improvement of the living environment. Public space that cannot meet the demand of living quality will lead to the replacement of original residents by less affluent residents, which will accelerate the decay of the estates, resulting in a larger number of demolition and new construction. Through the regeneration of public space, it can reduce future regeneration demand.

Meanwhile, the regeneration of public space solves social problems and makes the neighborhood more livable, vibrant, and aesthetically pleasing.

The problem of aging is particularly serious in the new workers' estates. Therefore, during the renewal process, special attention is paid to the experience of the elderly, to adapt to the living habits of the elderly, and to meet the needs of the elderly. But the design is not just for the elderly, the estate is still a mixed community, so we must also pay attention to how to allow different users to share space reasonably.

Through the research, learn how to balance the social resource among different stakeholders, to make the urban development more sustainable, the developer can always get their profits, and the residents can always find their best place to live.

2.METHODOLOGY

Methodology framework

The geo-design framework in essence is a platform for multidisciplinary collaborative research, at the same time, it provides a clear process for research questions. In this study, borrowing from this framework's method of analyzing problems, to study the current situation (what is the current context, how does the context operate, and how is the current context), and the changing situation after adding Circular Construction concept (what is the new concept, what happens with the application of new concepts, and how will these changes happen). Under the guidance of this methodology framework, the new workers' estates regeneration problem in Shanghai was analyzed.

Inductive

The research adopts the inductive method, starting from three different new workers' estates and researching three different regeneration strategies, then applying these strategies to various types of new workers' estates respectively, so as to predict the flow direction and amount of the entire circular construction network. Using this method helps me have a detailed understanding of material types, material production and consumption, and regeneration strategies at the beginning of the study so that the establishment of the network is more scientific.

Case study and literature review

Although many cases mention the application of circular construction technology in the design process, most of the examples do not describe in detail how to apply and which materials use these technologies. Therefore, the method of reusing materials, public space regeneration design can be learned from the case study. But most of the specific recycling methods come from papers of construction technology. How to connect the circulation technology with the space design lacks relevant cases.

3.PROBLEMS AND DIFFICULTIES

Research content

The research object, content, and method changed a lot during the process of research.

The initial research object was the large number of high-rise buildings in Shanghai. However, after research, the number of high-rise buildings that are badly in need of being demolished or renovated is not large, so the research is lack of generality. Therefore, to study the history of Shanghai's urban development, select a building type that is currently undergoing a preliminary transformation. It has a significant demand for regeneration shortly in the future, produces a large amount of waste while has few related studies. The new research object is the new workers' estate with a history of 30-70 years in Shanghai.

The original research content is to evaluate the new workers' estates in Shanghai, select different types of communities, and propose different regeneration strategies according to their current conditions. That is to say, based on the analysis and indicators, the decision is made as to which estates need to be demolished, which need to be refurbished, and which only need to be maintained. In other words, we know which communities will generate waste building materials, which communities require additional building materials, and the amount of materials generated and needed. According to their different regeneration conditions, different material flows will be formed, which combine with the city's infrastructure to create a circular construction network. On this basis, select cases to design the public space at the estate scale.

Due to the lack of data, technology, and knowledge, the research methods of the above research content are difficult to realize, and the research methods have changed. Directly select three cases, corresponding to three different regeneration methods. Starting with the regeneration of neighborhood-scale public spaces, learn the types of materials involved, and calculate the flow of materials. And on this basis, to build the circular construction network.

Data

The main reason for the change in the research content is insufficient data. It is hard to find accurate building age data for each community. At the same time, the assessment of the current status of the community needs to be supported by a large number of subjective and objective data contains building structure safety, environment, and facility use status, vacancy rate, land property rights, and land ownership. These data are difficult to obtain or replaced by other indicators. It is a process that requires multi-disciplinary collaboration. This evaluation cannot be completed in this study. Therefore, instead of classification, directly selecting representative cases, after the government has completed the overall assessment, they will be completely demolished or partially regenerated.

Techniques

In the entire project’s research process, circular construction technology is essential. Through a literature review of a large number of methods for recycling various materials, the material’s reusability, and the ratio of raw materials and secondary materials in new materials are summarized. Because the data is very different in different papers, the average of various data is selected as the result, so the calculation results cannot fully guarantee the scientificity.

At the same time, there are many methods of recycling, and some methods are too elaborate and small scale (such as some recycled street furniture), which is difficult to be applied on a large scale under the current situation. There is no in-depth research on this part of recycling technology.

Besides, the current circular construction techniques’ primary material recycle process is mainly based on the re-production of the same type of materials, which is not innovative enough.

Fieldwork and investigation

Although many cases mention the application of circular Through the survey, I have an overall understanding of residential areas such as new workers’ estate and investigated the problems of public space, the ownership of property rights, the user’s demand for space, and the user’s views on circular construction. And in the process of investigation, only the regeneration projects carried out can be investigated, but the specific amount of materials consumed during the transformation process cannot be known.

Due to the behavioral characteristics of people returning to their hometowns during the Chinese New Year, Shanghai, as a city with a large external population, will significantly reduce the number of people who can conduct investigations during this time, so the field trip arrangements are advanced before P2. At this stage, the research object is not precisely the same as the final design sites.

One of the final selected cases did not carry out a field investigation, and the results of the online investigation are not ideal, only get a general understanding of the community environment and surrounding facilities. The rest of the information is obtained through online materials.

Zoom in cases

Corresponding to the three regeneration methods, three cases were selected. Since demolition is equivalent to designing a new community, no in-depth design of this kind of example is done. The key research case is the case of refurbishment. In this case, there are partial demolition or reconstruction of buildings, which produce waste materials. At the same time, the regeneration of public spaces requires materials. On-site reuse and off-site recycling can occur at the same time. It is the more complicated one in the three regeneration process.

However, the transformation of the other type of maintain category requires more research. At present, only a micro-regeneration strategy is given for this type of estates and no more in-depth study. The fundamental difference between these two types of regeneration is whether there is on-site reuse. The impact of this difference on the spacial design and the large-scale circular network needs further research.

4.MODULARITY AND GENERALIZATION

The concept of modularity comes from the strategy proposed in the research process to reduce the materials consumed in future regeneration, improve the reusability of materials, and carry out a reversible design. The application of modular materials facilitates the application of modules directly to other locations or sites in the future regeneration process, reducing the in-between process of dismantling and reprocessing. Therefore, the design flexibility is guaranteed. The modularity usually means prefabricated industrial production, reducing material consumption, improving construction efficiency, and reducing pollution. At the same time, the combination of modules creates more possibilities for public spaces.

Another advantage of modularity is its ease of generalization. The same modules can be used in different scenarios, and various types of residential communities can divide the public space into flexible grids and apply these modules according to functional requirements. Therefore, this type of design can be more easily to be widely used.

There are also disadvantages of modularity.

- From the perspective of flexibility, the products used in modular grids and modules should be processed specially. It means that most of the current materials need to be remanufactured for recycling. And the secondary products must be processed according to the module, which makes them not as flexible as the common ones. If the modulus is different, the material cannot be applied. To complete the modularization of all products requires a long time and also requires some additional processing.
- The modules cannot fully match the sites without modular design. The new workers’ estates are all old urban area which are not designed by modulus. Therefore, when the modules are applied, there will be remaining space that cannot be covered.
- The unification of modulus is a difficult thing. The most suitable modulus at this stage may change in the future. From this perspective, the module’s ability to adapt to future changes is weak.
- The size of a single module limits the space. To obtain more space, there is a need to combine multiple modules, and the combined space may be larger than the required space, resulting in waste of space.
- The design is not fully context or user specific, which could cause spatial monotony.

While compared to reusing the products directly, the advantages of modularity, such as its speed of construction, ease of generalization, and sustainability over a longer period of time, make it still a potential design method. Based on the premise that before the completion of large-scale modular production, circular technology will not undergo a tremendous change, modularity is a potential design method to achieve this longer-term sustainable development.

The thesis design is an experimental research using this concept. It supplies a framework and guideline of applying circular construction to public space design. The basic public spacial regeneration is made as a basis, and more design possibilities could be developed further by designers and residents.

In the application process, the diversity of a single module and the combination of multiple modules should be continuously developed to form different spatial experiences in similar spatial forms to avoid the monotony of public spaces. At the same time, combined with the modularity of the building, unify the modules and make a coordinated development.

5.CIRCULAR CONSTRUCTION NETWORK

The application of circular construction to urban regeneration requires not only material research and spatial design at the micro-level but also relies on the Circular Construction Network at the urban or even regional scale to achieve this process. The circular use of building materials is a complex process, including demolition, separation, collection, reprocessing, storage, transportation, and reconstruction. Therefore, it is necessary to rely on this network for centralized processing and distribution of various resources.

Although the evaluation method mentioned above cannot be fully implemented in this study, it is still an indispensable step in the construction of this network. In the form of strategy, this can be described as the surveys and investigations required by each stakeholder to complete this step, which, as a result, shows how new workers’ estates should be classified. After completing this classification, we can know the direction of material flow (where waste materials come from and where secondary materials are used). Combined with the calculation of small-scale material recycling applications, and the area of various types of new workers’ estates, the number of materials participating in this circular construction network can be roughly obtained.

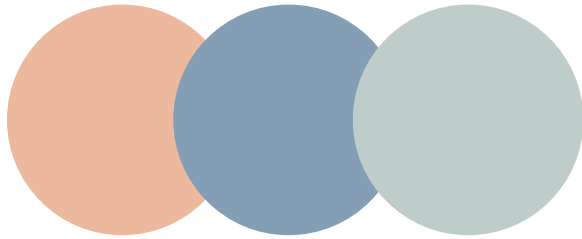
The next step is to learn how this network works and how to distribute it in urban areas. First, learn the existing formal or informal waste collection and processing infrastructure, and select functional nodes according to the importance of the area and their identity function in the city. These nodes serve as main demolition, separation, collection, reprocessing, and storage functions. At the same time, new nodes are added according to the predicted material flow. According to the principle of local priority, roughly draw the flow map of this network. To find the proper location for bio-based material production, look into the potential of different typologies of the landscape.

Analyze the different stakeholders participating in the network and let them collaborate to make the network more efficient. Build a collaborative online platform for the information of material flow. By using the techniques of material passport, building ID, and BIM system, the collaborative platform can have a more accurate judgment of the material offer and demands. The center of the platform can also be a real place for trading headquarter and stakeholder meetings as a knowledge hub.

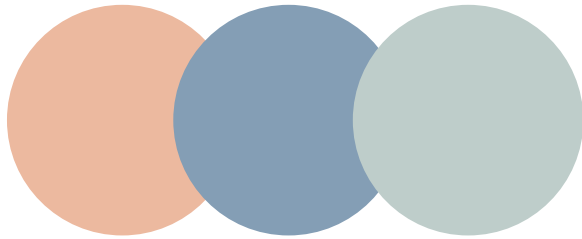
Through the above steps, the establishment of a collaborative circular construction network can make the entire design and research framework more complete and more implementable in the future.

While, the current research is based on several cases and shows the implementation of the ideas of circular construction network, but it still needs further researches to promote its practical application.

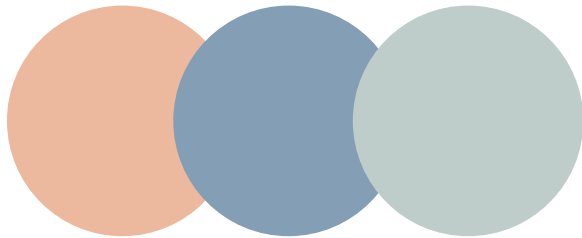
- According to the guideline, all new workers’ estates that are planned to be regenerated need to be evaluated and decisions made to form the network for supply and demands.
- The choice of construction industry node simplifies the actual situation, unable to obtain specific flow data, and takes distance as the evaluation standard. In practical applications, the connections between various nodes are more complicated, and the benefit relationships between different links also need more detailed research.
- The infrastructure selected as transformation nodes needs a more comprehensive feasibility study to determine whether it is truly practicable.
- There are more nodes in the actual network than mapped points.
- The relationship between stakeholders is more complicated.
- Collaboration at different scales also requires a more specific management system.
- The actual project construction order is also affected by more factors.
- The laws and regulations regarding circular construction also need to be improved.



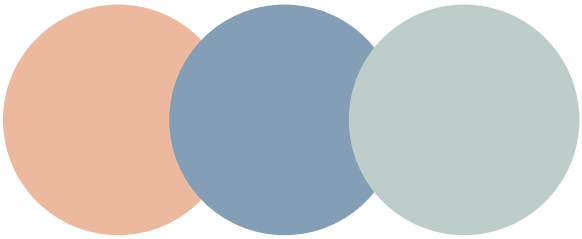
Current situation **Research** **Circular construction**



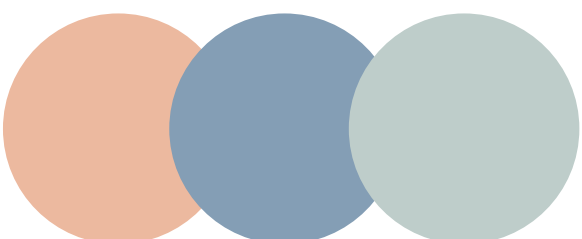
Demolition waste **Construction waste** **Decoration waste**



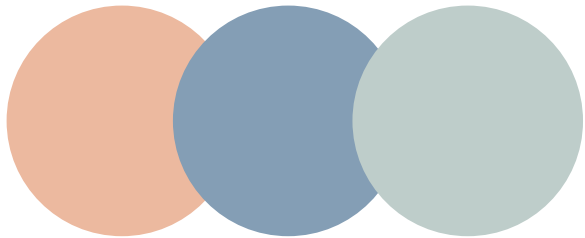
Demolition **Refurbishment** **Maintain**



On-site reuse **Recycle** **Bio-based material**



Elderly adaptive **Future adaptive** **Circular construction**



Public **Semi-public** **Semi-private**

12

REFERENCE

LITERATURE

Arora, M., Raspall, F., Cheah, L., Silva, A., Condeixa, K., Haddad, A., ... Verbeeck, K. (2019). Urban Mining: The City as a Source for Re-usable Building Materials. *Resources, Conservation and Recycling*, 19(2), 164–178. <https://doi.org/10.1016/j.scitotenv.2019.04.205>

Allmendinger, P., & Tewdwr-Jones, M. (2002). The communicative turn in urban planning: Unravelling paradigmatic, imperialistic and moralistic dimensions. *Space and polity*, 6(1), 5-24.

Amsterdam rainroof. [Online] Retrived from <https://www.rainproof.nl/toolbox/maatregelen/wadis>

Anne van Stijn . (2016). Rehabilitating China's crumbling high-rises. Repository TuDelft. Retrieved from <http://resolver.tudelft.nl/uuid:2f16244d-3918-43a0-bbcb-25f3689d0d77>

Bakaeva, N. V., Klimenko, M. Y., & Zamorov, A. A. (2018). Construction waste as a disperse system. *IOP Conference Series: Materials Science and Engineering*, 463(2). <https://doi.org/10.1088/1757-899X/463/2/022031>

Brent, A. C., & Pretorius, M. W. (2008). Sustainable development: A conceptual framework for the technology management field of knowledge and a departure for further research. *South African Journal of Industrial Engineering*, 19(1), 31–52. <https://doi.org/10.7166/19-1-105>

Brunner, Paul H. (2011). Urban Mining a Contribution to Reindustrializing the City. *Journal of Industrial Ecology* 15(3): 339–41.

Brunner, P. H. (2011). Urban mining a contribution to reindustrializing the city. *Journal of Industrial Ecology*, 15(3), 339–341. <https://doi.org/10.1111/j.1530-9290.2011.00345.x>

China Cement. [Online] Retrieved from <https://m.ccement.com/news/content/39564977875561.html>

CHYXX. (2018). 2019-2025 年中国建筑垃圾处理行业市场发展模式调研及投资趋势分析研究报告 . [Chinese construction waste from 2019 to 2025 Handling industry market development model investigation and investment trend analysis research report]. CHYXX, Retrived from www.chyxx.com

Circulaire woningen .(n.d.) . [Online] Retrieved from <https://www.superlocal.eu/circulaire-woningen/>

Coronado, M., Dosal, E., Coz, A., Viguri, J. R., & Andrés, A. (2011). Estimation of construction and demolition waste (C&DW) generation and multicriteria analysis of C&DW management alternatives: A case study in Spain. *Waste and Biomass Valorization*, 2(2), 209–225. <https://doi.org/10.1007/s12649-011-9064-8>

Cuperus, Y. (2001). An introduction to open building. Proceedings of the 9th Annual Conference of the 9th Annual Conference of the International Group for Lean Construction, 10. Retrieved from <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.202.7917&rep=rep1&type=pdf>

Cuperus, Y. (2003). Mass Customization in Housing an Open Building / Lean Construction Study. *Dense Living Urban Structures*, 1–13.

Chen Jun. (2007). Discussion on Estimation Method of Demolition Construction Waste. *Environmental Sanitation Engineering*, vol 15, no 6,2-3.

DB34/T 1016-2009. 安徽省地方标准 – 热轧再生钢筋 . [Anhui Provincial Standard-Hot rolled rebar]. Retrieved from <https://wenku.baidu.com/view/967f0696f011f18583d049649b-6648d7c0c70836.html>

Ding Guijie.(2007). The new estate for workers:'happy life for ever'[D]. Tongji University, Shanghai, China. Retrived from <http://kns.cnki.net/kns/detail/detail.aspx?FileName=2008051958.nh&DbName=CDFD2008>

Detroit Residential Parcel. (2010).Survey "Detroit Residential Parcel Survey" (PDF). p. 26.

Ekins, P., Simon, S., Deutsch, L., Folke, C., & De Groot, R. (2003). A framework for the practical application of the concepts of critical natural capital and strong sustainability. *Ecological Economics*, 44(2–3), 165–185. [https://doi.org/10.1016/S0921-8009\(02\)00272-0](https://doi.org/10.1016/S0921-8009(02)00272-0)

Esa, M. R., Halog, A., & Rigamonti, L. (2017). Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy. *Journal of Material Cycles and Waste Management*, 19(3), 1144–1154. <https://doi.org/10.1007/s10163-016-0516-x>

Fryslan, Bart Voelkers, & Eric Voss. (2017). A ROADMAP FOR BUILDING CIRCULAR VALUE CHAINS. Report on Synergic Circular Economy across European Regions SCREEN.

Ge Yan, Y. Guan, M, Nie. (2017). 上海城市更新的政策演进特征与创新探讨 [J]. [The Evolution Character and Innovation Research of Urban Regeneration Policy in Shanghai], *Shanghai City Planning*, 2017(05):23-28.

Ghisellini, P., Ripa, M., & Ulgiati, S. (2018). Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector. A literature review. *Journal of Cleaner Production*, 178, 618–643. <https://doi.org/10.1016/j.jclepro.2017.11.207>

Gordon Mathews. (2018).Ghetto at the center of the world Chungking Manshions, Hong Kong

Gu Song, T. Lei, & J. Tao. (2012). 再生混凝土配合比设计及早期强度试验研究 . [Recycled concrete mix proportion design and early strength test research]. *Industrial Building*, (04), 1-4. doi:10.13204/j.gyjz2012.04.002.

Gu Wenyuan. (2013). 彭浦新村街道智慧社区养老系统的设计与实现 . [Design and Implementation of Pengpu Estate Smart Community Pension System]. Dalian University of Technology, Dalian, China.

Guldmann, Eva. (2017). Best Practice Examples of Circular Business Models.

Habraken, N. J., Valkenburg, B., & Teicher, J. (1999). Supports : an alternative to mass housing. (2nd ed.) Newcastle

upon Tyne: Urban International Press.

Haile, M. T., & Hartono, Y. D. (2017). Current Practices of Construction and Demolition Waste Management (CDWM): Based on Observations at Swedish Construction Site. 1–98. Retrieved from <http://publications.lib.chalmers.se/records/fulltext/251973/251973.pdf>

Healey,P. (1996). The communicative turn in planning theory and its implications for spatial strategy formation, *Environment and Plannng B*, vol 23, no 2.

Healey,P. (1997). Collaborative planning: shaping places in fragmented societies, Basingstoke: Macmillan.

Healey,P. (1998). Collaborative planning in a stakeholder society, *Town planning review*, vol 69,no 1.

Healey,P. (2003). COLLABORATIVE PLANNING IN PERSPECTIVE, *Planning Theories*, Vol 2(2): 101–123

Ho, D. C. W., Yau, Y., Poon, S. W., & Liusman, E. (2012). Achieving Sustainable Urban Renewal in Hong Kong: Strategy for Dilapidation Assessment of High Rises. *Journal of Urban Planning and Development*, 138(2), 153–165. [https://doi.org/10.1061/\(ASCE\)UP.1943-5444.0000104](https://doi.org/10.1061/(ASCE)UP.1943-5444.0000104)

Hossain, M. U., & Ng, S. T. (2018). Critical consideration of buildings’ environmental impact assessment towards adoption of circular economy: An analytical review. *Journal of Cleaner Production*, 205, 763–780. <https://doi.org/10.1016/j.jclepro.2018.09.120>

Hu Huaru, Wang Lizhou. (2017). 从增量开发到存量运营，地产变局来临.[From incremental development to stock operations, real estate changes are coming]

Hu, Y., & Poustie, M. (2018). Urban mining demonstration bases in China: A new approach to the reclamation of resources. *Waste Management*, 79, 689–699. <https://doi.org/10.1016/j.wasman.2018.08.032>

Hu Weifan, Zhang Zixue.(1993). Research and development of recycled cement concrete. *Concrete and cement products*. 1993.(2): 15 ~ 18

Huang, Beijia & zhao, feng & Fishman, Tomer & Chen, Weiqiang & Heeren, Niko & Hertwich, Edgar. (2018). Building Material Use and Associated Environmental Impacts in China 2000-2015. *Environmental Science & Technology*. 52. 10.1021/acs.est.8b04104.

Huang Sha. (2016). 产权交易视角下的城市更新策略研究[J]. [Urban Renewal Strategy in Perspective of Property Transaction]. *Shanghai City Planning*, 2016(02):77-82.

Huuhka, S., Lahdensivu, J. (2016). Statistical and geographical study on demolished buildings. *Build. Res. Inform.* 44 (1), 73–96.

Jacobs, J. (1969). *The Economy of Cities*. Random House, New York.

Jin Yunfeng, Zhou yan, & Wu Yubin. (2019). 上海老旧社区公共空间微更新路径探究. [Research on the micro-renewal path of public spaces in old communities in Shanghai]. *Residential Technology*, 39(06):58-63.

Jiang Shanhong. (2016). 中国社区规划中协作关系的实践研究——以厦门市三种类型的社区规划为例. [Practical Research on Collaborative Relationship in Chinese Community Planning-Taking three types of community planning in Xiamen as an example][A], 2016 China Urban Planning Annual Conference Proceedings[C], China Urban Planning Association.

Kendall, S., & Teicher, J. (2002). Residential Open Building (Vol. Taylor & Francis eLibrary ed). London: Spon Press. Retrieved from <http://search.ebscohost.com.tudelft.idm.oclc.org/login.aspx?direct=true&db=nlebk&AN=68612&site=e-hostlive>

Koutamanis, A., van Reijn, B., & van Bueren, E. (2018). Urban mining and buildings: A review of possibilities and limitations. *Resources, Conservation and Recycling*, 138, 32–39. <https://doi.org/10.1016/j.resconrec.2018.06.024>

Lacy, P.; Keeble, J.; McNamara, R.; Rutqvist, J.; Haglund, T.; Cui, M.; Cooper, A.; Pettersson, C.; Kevin, E.; Buddemeier, P.; et al. Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth; Accenture: Chicago, IL, USA, 2014. Available online: <https://accntu.re/2cR5sVq>

Li Fengqing. (2007). 上海工人新村生态保护改造设想与操作.[Imagination and Operation of Ecological Protection and Transformation of Shanghai Workers' New Village]. Retrived from <https://www.docin.com/p-925597041.html>

Li Yanqiong. (2006). 我国城市建筑垃圾的循环利用. [Recycling of urban construction waste in China]. *Sichuan Data Inside*, 6, 16-17.

Liu Jiangfei, & Yao Yuan. (2019). 西北首例城市拆迁建筑垃圾再生砖渣轻骨料混凝土顺利施工[J]. [Northwest's first case of urban demolition construction waste recycled brick slag light aggregate concrete construction]. *Concrete*, 2019(05):160. http://www.hnt188.com/news_view.asp?id=26111

Liu Jingjing, (2016). 上海各区建设建筑垃圾中转站. [Construction waste transfer stations in Shanghai]. *Youth Daily*. <http://www.gczz.org/html/newslist/?771-0.html>

Lv Wenqian. (2014). The research of metabolism of urban residential buildings- the case of Beijing. *Nanjing Agricultural University*.

Mah, A. (2012). Demolition for Development: A Critical Analysis of Official Urban Imaginaries in Past and Present UK Cities. *Journal of Historical Sociology*, 25(1), 151–176. <https://doi.org/10.1111/j.1467-6443.2011.01406.x>

Matthias Heinrich, & Werner Lang. (2019). Materials Passports- best practice. BAMB. Retrieved from https://www.bamb2020.eu/wp-content/uploads/2019/02/BAMB_MaterialsPassports_BestPractice.pdf

Metabolic. (2018). Urban Mining and Circular Construction – what, why and how it works. [Online] Retrieved from <https://www.metabolic.nl/news/urban-mining-circular-construction/>

Natural, M., & Disputes, R. (1987). Introduction to Collaborative Process. Program, (1).

Neumayer, E. (2013). Weak versus Strong Sustainability. *Weak versus Strong Sustainability*, (2005), 1–4. <https://doi.org/10.4337/9781849805438>

Purbani, K. (2017). Collaborative planning for city development. A perspective from a city planner. *Scientific Review Engineering and Environmental Sciences*, 26(1), 136–147. <https://doi.org/10.22630/PNIKS.2017.26.1.12>

Qin Huahu. (2001).中国绿色建材的发展概况 [J] . [Overview of the development of green building materials in China].*Urban Development*,(11)-7714

Riera Pérez, M. G., Laprise, M., & Rey, E. (2018). Fostering sustainable urban renewal at the neighborhood scale with a spatial decision support system. *Sustainable Cities and Society*, 38(January), 440–451. <https://doi.org/10.1016/j.scs.2017.12.038>

Rijkswaterstaat & RIVM. (2015). Circular economy in the Dutch construction sector - A perspective for the market and government – Adapted

Scheinberg, A. (2011). Value added: modes of sustainable recycling in the modernisation of waste management systems. *Wageningen University, Gouda, The Netherlands*.

Schneider, T., & till, J. (2005). Flexible housing: Opportunities and limits. *Architectural Research Quarterly*, 9(2), 157–166. <https://doi.org/10.1017/S1359135505000199>

Seo, J. K. (2016). Housing Policy and Urban Sustainable Development: Evaluating the Process of High-rise Apartment Development in Korea. *Urban Policy and Research*, 34(4), 330–342. <https://doi.org/10.1080/08111146.2015.1118373>

Shanghai research center on aging. (2019). Statistical information on the monitoring of the elderly population and the undertakings in Shanghai. <http://www.shrca.org.cn/News/detail.aspx?ID=6892&Page=0>

Shao Zheng, Yan Hongliang. (2018). 上海既有高层住宅外墙更新改造调研与分析. [Investigation and Analysis of the Exterior Walls Renewal of Existing High-rise Residential Buildings in Shanghai]. *Residential Techniques*, 11, 11-20.

Shen Xiaokui. (2018). 一种建筑垃圾再生料制备环保渗水砖的方法 [P]. [Method for preparing environment-friendly water-permeable bricks by using construction waste recycled materials, Guangdong. CN108609923A,2018-10-02.

Steinitz, C. (2012). A framework for geodesign : Changing geography by design. *Redlands: ESRI*.

Stephan, A., & Athanassiadis, A. (2018). Towards a more circular construction sector: Estimating and spatialising current and future non-structural material replacement flows to maintain urban building stocks. *Resources, Conservation and Recycling*, 129(November 2017), 248–262. <https://doi.org/10.1016/j.resconrec.2017.09.022>

Stonecycling. (2018). <https://www.stonecycling.com/waste-basedbrick>

Suo Jian. (2012). 发达国家既有集合住宅再生理论综述

[Overview of representative theories on the sustainable renovation of existing collective housing in the developed countries]. *New Architecture*.

Suo Jian. (2014). 中外城市既有住宅可持续更新研究. [Study on sustainable renovation of urban existing housing at abroad and China]. Dalian University of Technology, Dalian, China. Retrieved from <http://epub.cnki.net/kns/detail/detail.aspx?FileName=1015573812.nh&DbName=CDFD2015>

Suo Jian, Qian, Z., & Yue, Fa. (2018). Thoughts on the Practice and Existing Problems of Urban Housing Quality Improvement in China. 33(5), 1–5. <https://doi.org/10.13791/j.cnki.hsfwest.20180501>

Talen, E. (2014). Housing demolition during urban renewal. *City and Community*, 13(3), 233–253. <https://doi.org/10.1111/cico.12070>

The Economic Times. (2019). Read more at: http://economictimes.indiatimes.com/articleshow/69919005.cms?from=mdr&utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

Tu Huijun, Y. Feng ,J, Zhang , & Y. Xuan. (2019). 上海工人新村适老改造更新模式探究——以鞍山三村为例 [J]. [A Study on Elderly-adaptive Rehabilitation of Shanghai's New Worker's Estate]. *Architectural Journal*.2019(02):57-63.

Xiaofei, S., Yi, Q., Zongguo, W., Lili, L., Guijuan, S., & Jinhui, L. (2017). Research on Urban Mining Development in China. *Chinese Journal of Engineering Science*, 19(4), 97. <https://doi.org/10.15302/j-sscae-2017.04.015>

Xiaolin Yang. (2016). 基于体系分离的高层开放住宅设计方法研究. [Research on the design method of the open high-rise residential building based on the seperation system]. *South China University of Technology, Guangzhou, China*.

Xiang Xuan.(2011). The research of workers community residential architecture and outdoor environment in Jiangsu, Zhejiang and Shanghai from 1949 to 1978- research based on spatial form and form characteristics[D]. Jiangnan University, Wuxi, China. Retrived from <http://kns.cnki.net/kns/detail/detail.aspx?FileName=1011082824.nh&DbName=CMFD2011>

Wang, H., Shen, Q., Tang, B. S., & Skitmore, M. (2013). An integrated approach to supporting land-use decisions in site redevelopment for urban renewal in Hong Kong. *Habitat International*, 38(1), 70–80. <https://doi.org/10.1016/j.habitatint.2012.09.006>

Wang Weiqiang. (2020). Interview ‘new workers’ estate is no longer a social experiment carrier, but it is a memory that Shanghai should retain’, YICAI, <https://www.yicai.com/news/100504445.html>

Wang Xiang. (2016). 既有住区外环境空间类型化及品质提升策略研究 – 以大连市为例. [Study on the types and quality promotion strategies of the residential external environment-taking Dalian as an example]. Dalian University of Technology, Dalian, China.

Wang, Y., & Xiang, P. (2019). Investigate the Conduction Path

of Stakeholder Conflict of Urban Regeneration Sustainability in China : the Application of Social-Based Solutions.

Wassenberg, F. (2011). Demolition in the Bijlmermeer: Lessons from transforming a large housing estate. *Building Research and Information*, 39(4), 363–379. <https://doi.org/10.1080/09613218.2011.585104>

Wong, J. F. (2010). Factors affecting open building implementation in high density mass housing design in Hong Kong. *Habitat International*, 34(2), 174–182. <https://doi.org/10.1016/j.habitatint.2009.09.001>

Wu Xianguo. (2003). Generation and composition analysis of construction waste. *Architecture Technology*, vol 2, 105–106.

Xiang Xuan. (2011). 1949–1978 江浙沪工人新村住宅建筑及其户外环境研究. [Research on 1949–1978 Residential Buildings and Outdoor Environment of Jiangsu, Zhejiang and Shanghai New Workers' Estates]. Jiangnan University.

Xu, K., Shen, G. Q., Liu, G., & Martek, I. (2019). Demolition of existing buildings in urban renewal projects: A decision support system in the China context. *Sustainability (Switzerland)*, 11(2), 1–22. <https://doi.org/10.3390/su11020491>

Xu Xiaofeng. (2019). 新马克思主义视角下的城市空间演变 [Urban Spatial Change From the Perspective of Neo-marxism: A Case Study of Workers' Estate in Shanghai, *City Planning Review*, VOL.43 NO.7 JUL.

Xue, Y. (2018). Sustainable urban mining: the case of China.

Yan, L., & Jun, B. (2014). Game theory analysis of demolition and reconstruction urban renewal. *Applied Mechanics and Materials*, 484–485, 757–762. <https://doi.org/10.4028/www.scientific.net/AMM.484-485.757>

Yang Chen. (2019). 从模范社区到纪念地：一个工人新村的变迁史. [From model community to monumental site: a workers' village through history]. Tongji University Press, 2019. 10. ISBN: 9787560885391

Yang Junli. (2018). Study on the evolution of urban residential space structure in Shanghai

Yu Kongjian, D. Li, H. Yuan, W. Fu, Q. Qiao, & S. Wang. (2015). “海绵城市”理论与实践 [J]. [“Sponge City” Theory and Practice]. *City Planning Review*. 2015, 39(06): 26–36.

Yu, B., Wang, J., Li, J., Zhang, J., Lai, Y., & Xu, X. (2019). Prediction of large-scale demolition waste generation during urban renewal: A hybrid trilogy method. *Waste Management*, 89, 1–9. <https://doi.org/10.1016/j.wasman.2019.03.063>

Yu, T., Shen, G. Q., Shi, Q., Zheng, H. W., Wang, G., & Xu, K. (2017). Evaluating social sustainability of urban housing demolition in Shanghai, China. *Journal of Cleaner Production*, 153, 26–40. <https://doi.org/10.1016/j.jclepro.2017.03.005>

Zhao Jun, Liu Qiuxia, Lin Liqing, Qian Guangren, Xiao Jianzhuang, 2013, Evolution and comparison of construction waste of large cities in China, 大城市建筑垃圾产生特征演变及比较, 44(03): 1297–1304.

Zhao Weiming, Gu Xiaoying, Yang Jing, Chen Chen. (2008).

漕北大楼节能综合改造工程探究. [Study of Comprehensive Reconstruction for Energy Saving of Caobei Building]. *Residential Techniques*, 05, 50–54.

Zheng, H. W., Shen, G. Q., & Wang, H. (2014). A review of recent studies on sustainable urban renewal. *Habitat International*, 41, 272–279. <https://doi.org/10.1016/j.habitatint.2013.08.006>

Zhou Jian, Yu Jing, Chen Yulu, Lu Tianzan, (2017), A Research on the Height Pattern in Shanghai's Overall Urban Design, 上海总体城市设计中的城市高度秩序研究, China Academic Journal Electronic Publishing House, doi: 10.16361/j.upf.201702007

Zhu Dongfeng. (2010). Research of urban construction waste disposal. South China University of Technology, Guangzhou, China.

Zhuo ling, & B. Chen. (2014). MU5.0再生骨料混凝土空心砌块配合比设计. [Mixed Proportion Design of Recycled Aggregates Concrete Hollow Block with MU5.0]. *Bulletin of The Chinese Ceramic Society*, (02), 271–276. doi: 10.16552/j.cnki.issn1001-1625.2014.02.049.

Zhu.X. (2014). GIS and urban mining. <http://www.mdpi.com/2079-9276/3/1235/pdf>

Zhu Xiu. (2016). 碎砖类骨料再生混凝土砌墙砖的制备方法及其基本力学性能研究. [Study on the preparation methods and the mechanical property of recycled brick aggregate concrete wall bricks]. Anhui University of Architecture. Retrieved from <https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD201701&filename=1016198388.nh>