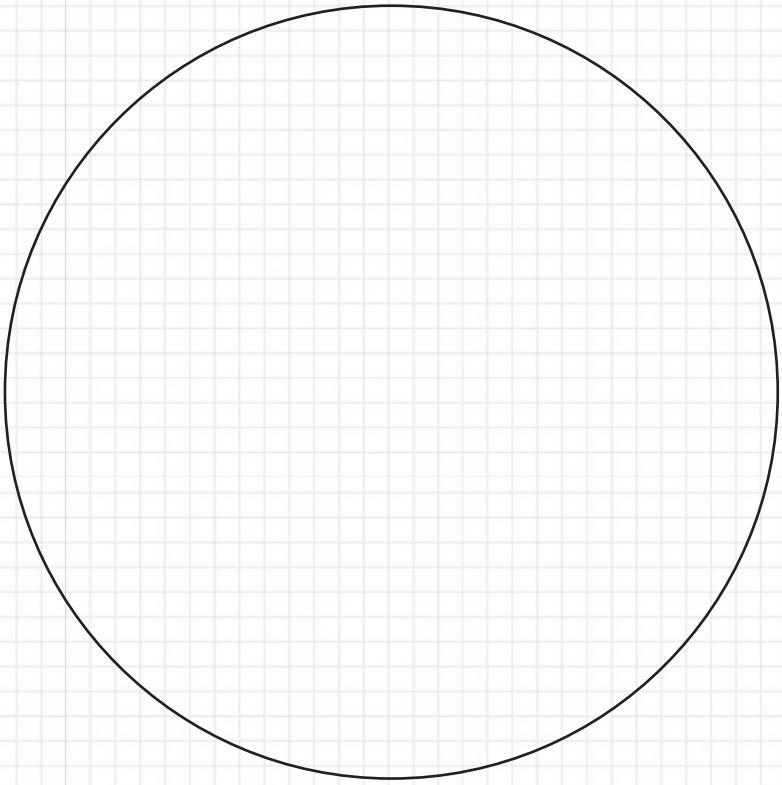

HUMANIZING HOUSTON

Construction & Water Resilient Design of Downtown Houston

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CONTENT

1 INTRODUCTION

Houston
Car-oriented city
Flooding issue
Downtown Houston

Fig. 1.1 | Photo of Houston

HOUSTON

NATURE & CULTURE

Houston is the most populous city in the U.S. state of Texas, the fourth most populous city in the United States, with an estimated 2018 population of 2,325,502(Bureau, U. S. Census, 2019). Located in Southeast Texas near Galveston Bay and the Gulf of Mexico, it is the seat of Harris County and the principal city of the Greater Houston metropolitan area. Comprising a total area of 637.4 square miles (1,651 km2),(Houston Texas Geography Profile, 2019.) Houston is the eighth most expansive city in the United States. The city of Houston was founded at the confluence of Buffalo Bayou and White Oak Bayou.
The economy of Houston since the late 20th century has a broad industrial base in energy, manufacturing, aeronautics, and transportation. Leading in healthcare sectors and building oilfield equipment.

GEOLOGY

Houston is a flat marshy area where an extensive drainage system has been built. The adjoining prairie land drains into the city which is prone to flooding. (Baddour, Dylan,2016). Underpinning Houston's land surface are unconsolidated clays, clay shales, and poorly cemented sands up to several miles deep.

CLIMATE

The city experiences two seasons; a wet season from April to October and a dry season from November to March.
During the summer, temperatures in Houston commonly reach over 90 °F (32 °C). The city reaches or surpasses this temperature on an average of 106.5 days per year, additionally, an average of 4.6 days per year reach or exceeds 100 °F (38 °C). (Now Data, 2016)
Houston has mild winters. In January, the normal mean temperature at George Bush Intercontinental Airport is 53.1 °F (12 °C), with an average of 13 days per year with a low at or below 32 °F. (Now Data, 2016)
Houston generally receives ample rainfall, averaging about 49.8 in (1,260 mm) annually based on records between 1981 and 2010. Many parts of the city have a high risk of localized flooding due to flat topography

ECONOMY

Houston is recognized worldwide for its energy industry—particularly for oil and natural gas—as well as for biomedical research and aeronautics. Renewable energy sources—wind and solar—are also growing economic bases in the city. (Alternative Energy in the Houston Region, 2011)
The Houston metropolitan area ranked first in Texas and third in the U.S. within the category of "Best Places for Business and Careers. (Badenhausen, Kurt, 2006)

Resource:https: Plan Downtown, CONVERGING, Culture, Lifestyle & Commerce
http://www.downtowndistrict.org/

HOUSTON

CAR ORIENTED URBAN AREA

Houston is a car-centered society and a fast growing urban conglomeration. This resulted in a massive urban sprawl with a transport system that relies heavily on car use. The highway system is center orientated with multiple surrounding ring roads. Currently, the construction of a 5th ring road has started. The current state of the infrastructure (road surface, signage and traffic coordination) is very poor with regards to Dutch standards. For example, traffic lights are only on a timed cycle. Currently public transportation is scarce, however, lately efforts have been made to implement a public transport system, this system is composed of a system of bus lines and three tram lines. There are plans for an additional two tramlines.

For years, Houston has been seen as a car-centric city. By and large, it still is. Fewer than 7 percent of city residents walk, bike or take transit to work, according to Census estimates and 77.2% of commuters driving alone to work in 2016

A commuting study estimated that the median length of commute in the region was 12.2 miles (19.6 km) in 2012. According to the 2013 American Community Survey, the average work commute in Houston (city) takes 26.3 minutes. (Sivak, Michael, 2015)

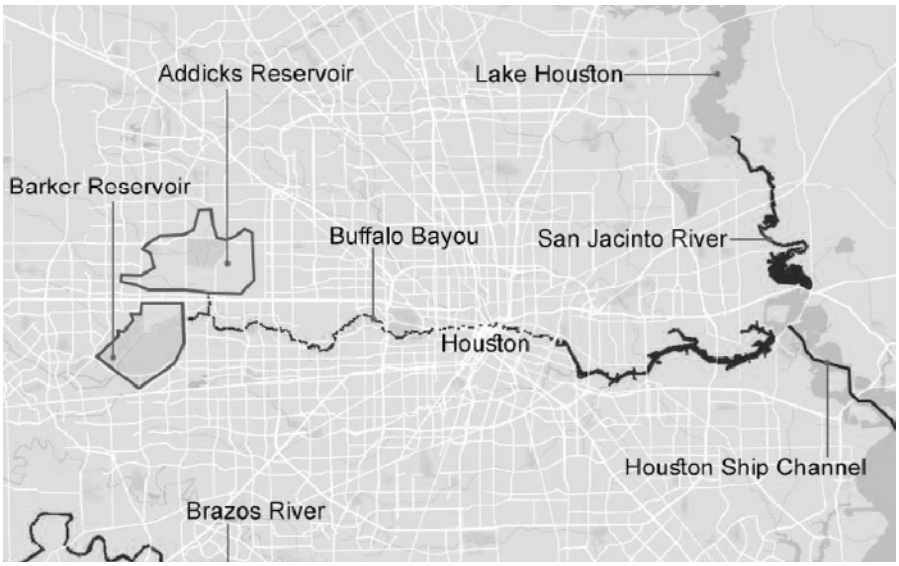
The car oriented infrastructure is shown in Fig.1.2, the road network covers the whole city, and spread to a large scale. The highway I-45 is shown by the pink line, and the photos in Fig.1.3 shows the car oriented infrastructures-highway, ground parking lots and parking garage in Houston.

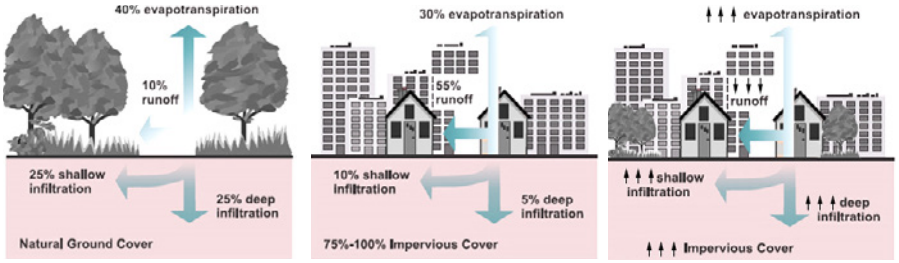
HIGHWAY I-45

The I-45 was officially built to relieve traffic from the I-69. However it also justified the partial demolishment of the fourth ward, a predominantly black neighbourhood. Currently, the main traffic flow on the I-45 is through traffic. It is, therefore, possible to redirect traffic to the I-69 without much added travel time. Removal of the I-45 will release downtown from the barrier that is the I-45 and will open up a lot of new development areas.

Resource: Downtown Commute Survey Executive Survety 2013, http://downtownhouston.org

Fig. 1.2 | Car-oriented infrastructure in Houston
Fig. 1.3 | Photos of car oriented facilities
Fig. 1.4 | Hurricane Harvey
Fig. 1.5 | Bayou and reservoirs
Fig. 1.6 | Water overflow increase





FLOODING ISSUE

CURRENT PROBLEM STATEMENT

HURRICANE HARVEY

Between August 25 and 30, 2017 Hurricane Harvey dropped substantial rainfall over the City of Houston and surrounding areas resulting in devastating urban flooding. (Fig. 1.4)
Almost 1/3 of the housing in Houston is affected by the big flood, 300000 housing is damaged by the flood and the government need125billion dollars to rebuild the damaged area.
Not only Hurricane Harvey, since ancient times Houston has been suffering the flooding issue, and in recent years, the flooding is more frequent and has a trend to be more serious for urban development.

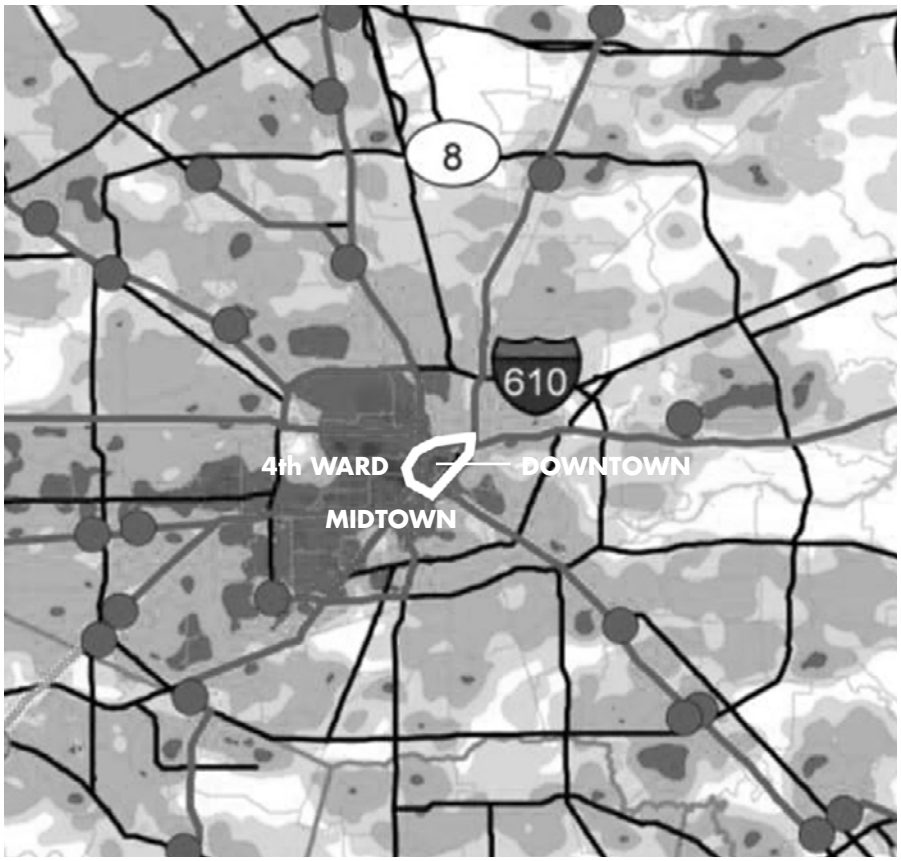
WHY DID HOUSTON FLOOD

-The city is flat.
"We have a slope that is less than one foot per mile and because of that, we have very slow draining systems." (Phil Bedient).
-Aging infrastructure
Many of the area's bayous are too small to even handle Houston's frequent heavy rainstorms.
The main bayou through downtown, Buffalo Bayou, "is pretty much still a dirt mud channel like you would have seen 100 years ago.
Besides, there are only two major reservoirs to hold storm water during heavy rain events, the Addicks and Barker reservoirs, which East, Bedient, and others say are inadequate. (Fig. 1.5)
-Rapid growth without zoning regulations
The city has a low density development over a large area based on vehicle traffic and the surface is covered by impermeable materials. When concrete is poured over green space, the city loses the capacity to absorb water. (Fig. 1.6)
-Geography and climate change play a role
The growing issue of climate change like sea level rise, warming ocean and increase rainfall also make it more serious.

HOW DOES HOUSTON DEAL WITH FLOOD

Local and regional planning to manage growth and protect ecologically sensitive areas
Site design to minimize land disturbance and paved surfaces, and to buffer water bodies with strips of vegetated land
Retention of storm water with facilities such as detention ponds and dry basins
Allowing storm water to percolate into the soil with infiltration facilities such as trenches and permeable or porous pavement
Vegetation that absorbs pollutants and assists percolation, used in facilities such as swales, constructed wetlands, and rain gardens

Resource:https://www.houstonchronicle.com/news/houston-weather/hurricaneharvey/article/Then-and-now-photos-show-how-Hurricane-Harvey-13155174.php



DOWNTOWN HOUSTON

THE CENTER OF HOUSTON

Since 2004, Downtown has experienced what is arguably the greatest resurgence in the city's history. More than $6 billion has been invested across a broad mix of urban uses: new parks and public spaces, new and renovated hotels, new multi-family residential developments, new and renovated office towers, renovations, and expansions to convention and theatre facilities, and continued investments in government facilities, infrastructure, and transit. (Plan Downtown CONVERGING, 2017)

LOCATION

Downtown is at the centre location of Houston. (Fig. 1.7) Its south side is Midtown, which is a mixed use area. It's west side is the 4th ward residential area. Its north side is a small part of industrial and storage area and then the widely spread residential area. The east side is the EaDo area, which is not developed efficiently but has great potential for urban redevelopment.

STATUS

As the centre of the fourth largest city in the United States, Downtown Houston is the core of a dynamic regional economy that is shaped by the convergence of geography, history, development, natural systems, and the diverse residents. At the heart of an eight county region, Downtown impacts the regional context, and the centre city impacts Downtown across these major areas: economy, infrastructure, transportation, education, living, cultural facilities, visitor and guest experience, parks and open space, resiliency. (Plan Downtown CONVERGING, 2017)

Fig. 1.7 | Location of downtown Houston
Fig. 1.8 | Photos of downtown Houston

Ground parking lot

Parking garage

Resource: Downtown Commute Survey Executive Survety 2013, http://downtownhouston.org

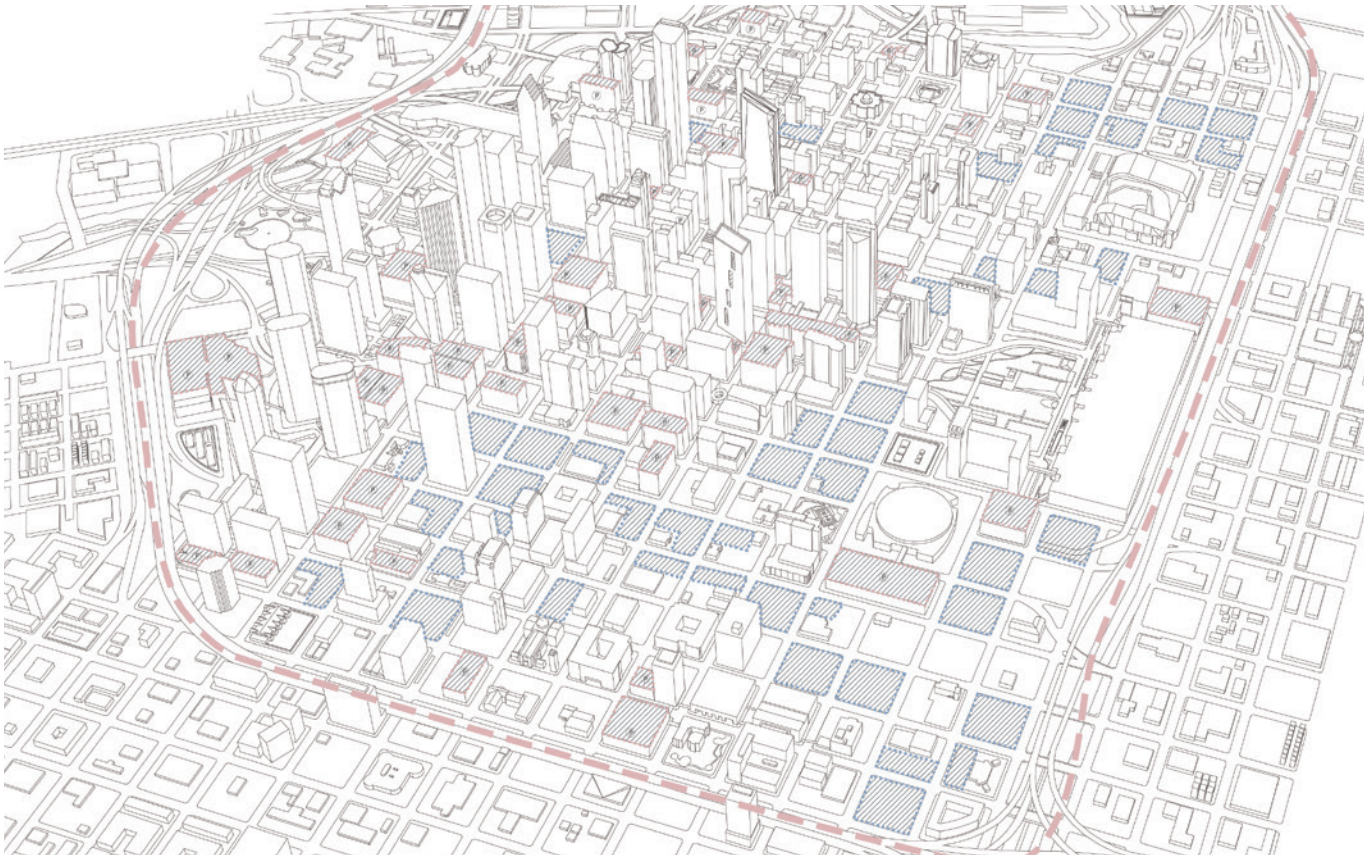


Fig. 1.9 | Parking area in downtown

Ground parking lot

Parking garage

CAR ORIENTED

Under the same situation, the downtown area is also a car oriented urban area. Although there have been some measures such as build the public transportation transition and parking space around the boundary of downtown. There are still too many cars in this area, which means need much space for car driving and car parking. Because people use private cars to travel, there are no people walking on the street, which makes the area lack vitality. (Fig.1.8)

LAND USE

Due to the car oriented situation, there is much space used for car parking. The parking space mainly has two types: ground parking lot and parking garage, and they are located as Fig.1.9 shown, which accounted for a large proportion of land use and the pink line is the redevelopment location of highway.

FLOODING

There is not so serious flooding problem in most of the downtown area.
There is a flooding risk along the Buffalo Bayou, and there are currently some buildings with the function of storage and industry which can be removed to avoid being damaged by the flooding. However, there are also some public function buildings like the school and jail need more measures to deal with the flooding.
On the south side of downtown, there is sometimes a problem with the overflow of heavy rains.
Because of the large proportion of impermeable surface in the downtown area, it worsens the flooding issue in the Bayou area.

2 VISION&STRATEGY

Context analysis
Houston workshop
Typology & Strategy

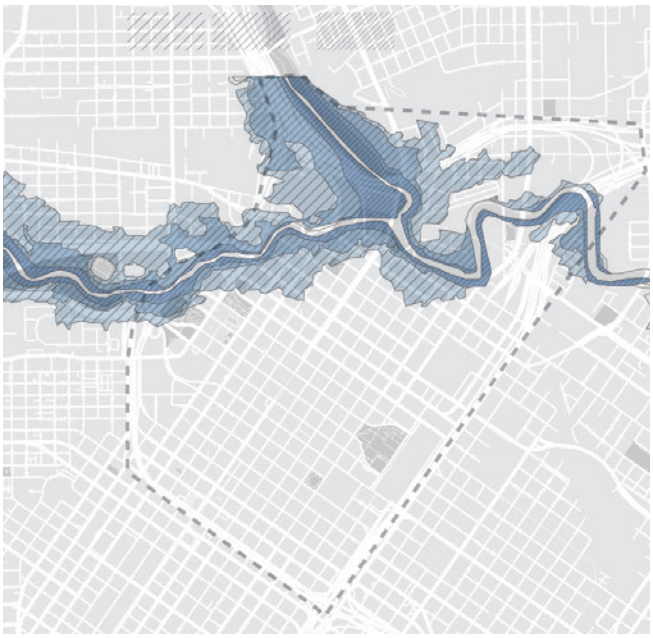


Fig. 2.1 | Surrounding situation
Fig. 2.2 | Flooding plain

CONTEXT ANALYSIS

TRANSPORT, WATER & LAND USE

Connection

Entrance from highway

Other areas

Redevelopment of highway

0.2% (500 years floodplain)

1% (100 years floodplain)

TRANSPORT

Downtown is surrounded by highways which is a barrier between downtown and neighbour areas. The connection between downtown and midtown, EaDo are more close as the blue arrows in Fig. 2.1 shown by public transportation, public space and public buildings. While the connection between downtown and 4th ward area is not so close, as there are few crossovers in function, it is mainly a natural barrier on the ground level.
There are several entrances from the highway to enter downtown. As the south part of I-45 is not used efficiently, it is planned to be removed and gives room for urban development.
Projected increases in population and employment in the Houston metropolitan area will contribute to additional traffic congestion on I-45. The roadway project is also needed to bring the roadway up to current design standards, which would improve safety and provide for more efficient movement of people and goods. As a designated evacuation route, an improved roadway will aid in an emergency evacuation. (North Houston Highway Improvement Project – Preliminary Drainage Study, AECOM)
Different modes of transportation collaborate together in the area, mostly motorized-private cars, bus and tram. The usage rate of public transportation is low comparing to the huge amount of private cars.

WATER

Downtown is located at the transition point from holding to depositing water. The Buffalo Bayou and White Oak Bayou meet here. The north part of the downtown area along the Bayou is on the floodplain, where has a possibility to be flooded by the100-year flood to 500-year flood. (Fig.2.2)
The other part of the downtown area is not on a floodplain, but some lower part still has a risk to be flooded by the overflow of rainwater, such as part of the I-45 highway.

Fig. 2.3 | Land use map
Fig. 2.4 | Parking map

LAND USE

The downtown area in a whole is mixed land use, containing offices, commercial buildings, residential, public and green space functions. However, different functions are always concentrated in different areas, in the sub areas, it is always mono function. The main function is office as the central business district, with some commercial and public buildings. The two big sports centre and the convention centre consist of the main entertainment area. (Fig. 2.3)
The parking garage buildings are all over the downtown area, and there are still many plots with the function of ground parking, where has a big potential to densify. (Fig. 2.4)

POTENTIAL

No problems, but opportunities.

As the situation is resulted because of people's lifestyle there, they enjoy this kind of lifestyle, so we do not think of it as a problem. However, people can act in a more sustainable way for a better future, so we see there are plenty of opportunities to change the lifestyle and then the paradigm of urban development.
There are some mains aspects for the potential of downtown Houston.

-Space for spatial development
The land use efficiency is not so high, the empty blocks and ground parking space have the potential for development.

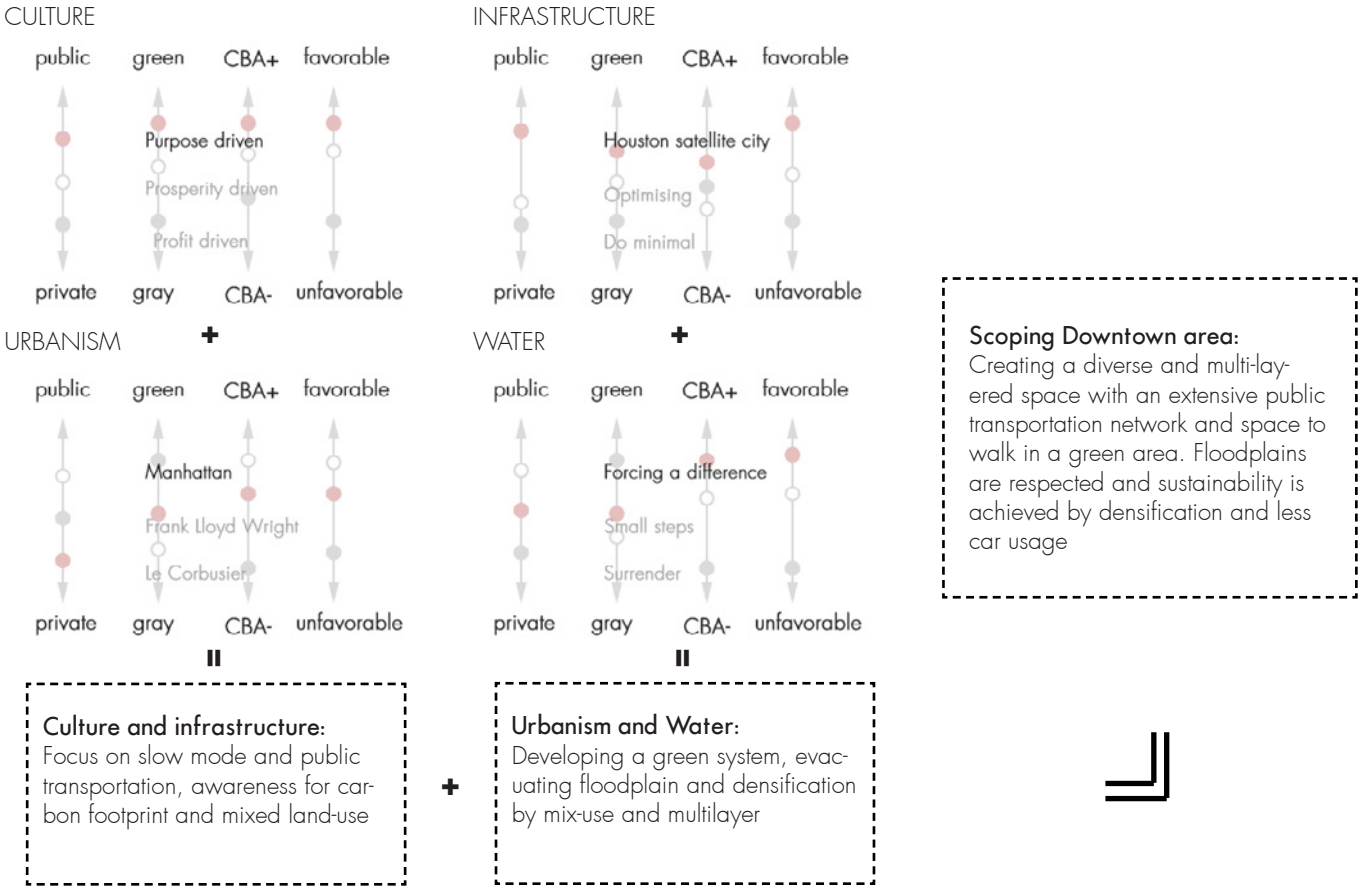
-Intensification of mixed land-use
One of the characteristics of downtown construction is high density, more dense and mixed use development can make downtown have more vitality.

-Development of a viable integrated urban transport system
The current mode of transportation is relatively simple. By integrating multiple modes of transportation, the accessibility and walkability of downtown will be improved.

-A more bubbling and vibrant city
By increase construction density, urban public life, urban vitality, accessibility and walkability, there is the potential for building a better human oriented downtown Houston.

Commercial
Residential
Public
Green & under used
Office

Parking garage
Ground parking lot



HOUSTON WORKSHOP

WHAT TO ACHIEVE?

SCOPING

Urbanism: Manhattan concept(densification and multilayer)
Water: Remove some impermeable infrastructure and replace with green space (assumption of reusing concrete)
Strict rules for urban planning on a city scale (rules on the green area, location of buildings at flood plains, buffer around the bayou) and other small design interventions.
Culture: incentives & awareness of culture change. Creating more awareness and facilitating changes in a positive way and small steps.
Infrastructure: An intelligent traffic management system will be installed in the entire city to increase flow and thus facilitate future traffic levels. The traffic lights will predict traffic better with the help of ground loop detectors and other optical electrical detectors. Big data will be used to analyze flow patterns and provide detailed traffic predictions on which the traffic management system can anticipate. Accelerated expansion and build of new LRV mass transit lines with multiple convenient and centrally located park and ride facilities that will ease car traffic demand to downtown.

Urbanism and Water: Developing a green system, evacuating floodplain and densification by mix-use and multilayer
Culture and infrastructure: Focus on slow mode and public transportation, awareness for carbon footprint and mixed land-use
Scoping Downtown area: Creating a diverse and multi-layered space with an extensive public transportation network and space to walk in a green area. Floodplains are respected and sustainability is achieved by densification and less car usage (As the diagram above shown)

VISION

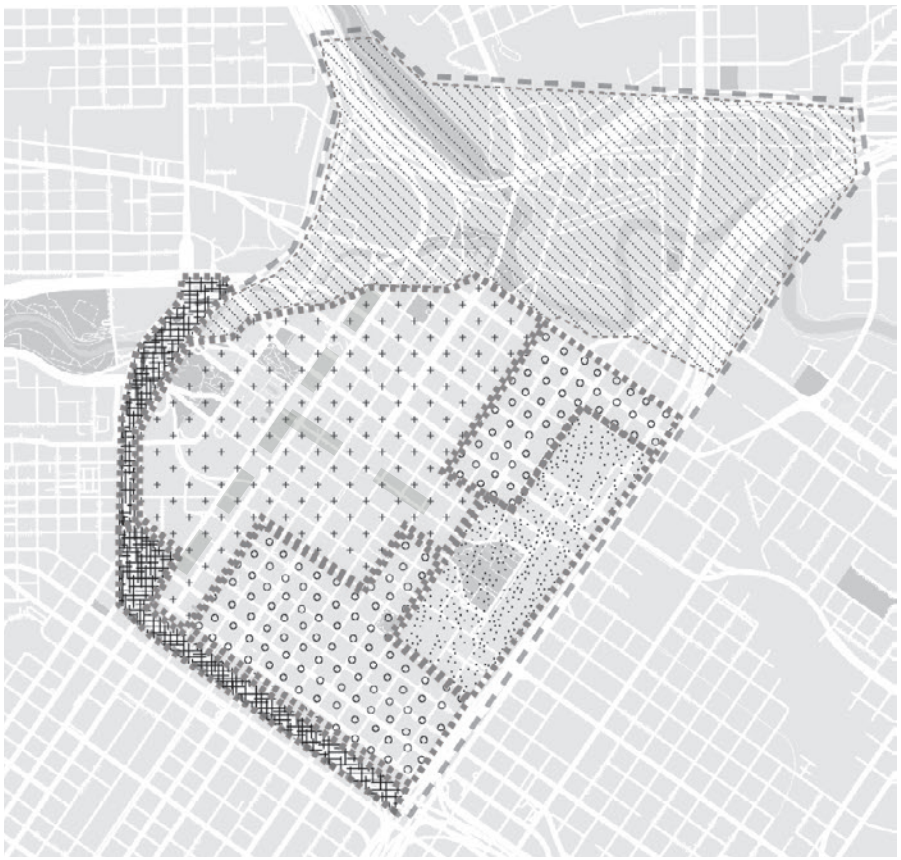
A human-oriented downtown Houston, where connectivity and resilience are leading.

MOTTO

"IN HUMANS WE TRUST"

METHODOLOGY

-Combine scoping and apply it on downtown area
-Divide the research area into different typologies
-Detailed developed measures per typology
-Combine measures into a final plan for whole downtown Houston
-Human oriented connectivity research on traffic
-Human oriented resilient design on smaller scale site



TYPOLOGIES

DIFFERENT FUNCTIONS IN DOWNTOWN

The whole downtown area is divided into five different sub areas according to different main functions and corresponding typology difference. (Fig.2.5)

BUFFALO BAYOU AREA

This is an undeveloped compared to the rest of the area with several buildings built in the floodplains where is most possibly flooded. Alongside the meandering river, and the bayou has steep banks which are not good for nature infiltration of water.

I-45 AREA

The existing highway infrastructure not used very well, and is planned to be removed. In current situation, it acts as a big parking place and shelter for homeless people. It is also a barrier between downtown and midtown. There is little open public space beneath the highway.

BIG-T AREA

This is the central business area with lots of high rise buildings.
Mostly the land use is mono-functional of offices and commercial buildings, which makes the big -T area has no vitality during the weekend and holidays.
The buildings are connected by an underground tunnel system but can hardly found by strangers.

CONVENTION AREA

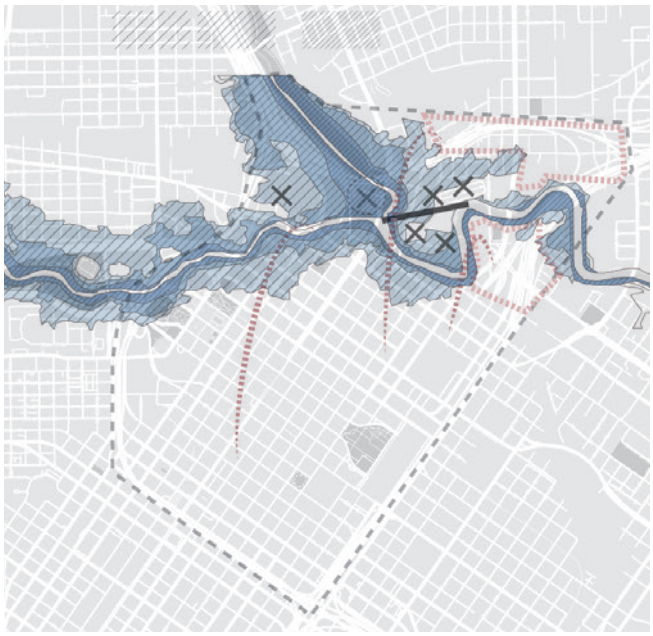
Surrounded by hotels, restaurants, bars and an amazing amount of parking areas. Well connected by public transportation and is the most active part in downtown when there is a game.

FUTURE HOUSING AREAS

Lots of ground floor parking lots and undeveloped area.
Lack of connection by public transportation and green space.

Fig. 2.5 | Typology map

- Buffalo Bayou area
- Big T area
- I- 45 area
- Convention area
- Future housing area



STRATEGIES

DIFFERENT FUNCTIONS IN DOWNTOWN

Fig. 2.6 | Measures of Buffalo Bayou area
Fig. 2.7 | Measures of I-45 area

Potential construction area
Water tunnel
Demolish
Green barrier
Commercial looking
Landscape looking
High line

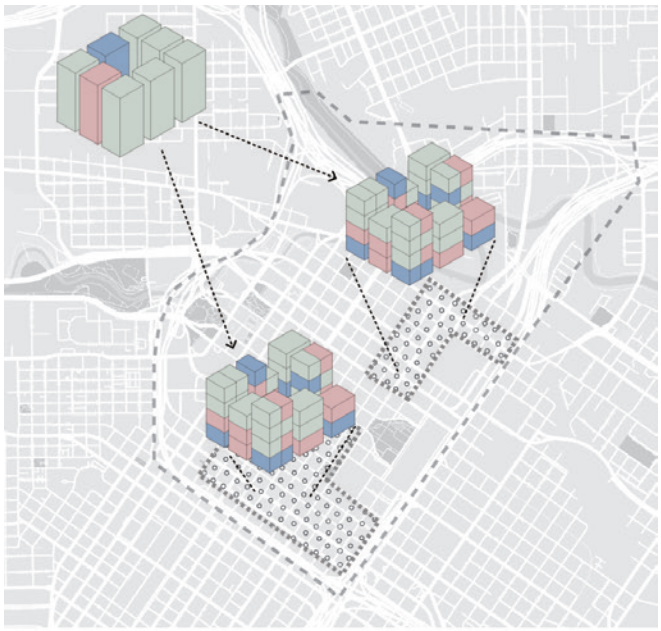
After divided into different areas, there are measures for each area's different characteristics, development potential and future development goals.
All the measures follow the scoping of downtown area - purpose driven in culture; satellite city concept in infrastructure; Manhattan concept in urbanism and forcing a difference in water.

BUFFALO BAYOU AREA

Potential: There is a large amount of green area for both recreation and water management function;
The flow speed is currently slowing down when passing this area, straighten the river to increase the water flow can decrease the possibility of flooding.
Measures: Move the buildings on the floodplain to other safe place and create open green space in site;
No densification in this area in recent years, even though not on floodplain;
For long term situation, densification in this area is allowed after a decrease of flooding risk but try not to build on floodplain either. (Fig. 2.6)

I-45 AREA

Potential: The I-45 highway can be redeveloped into a green urban area: It can have an integrated use of green area and commercial or residential functions to make the land use more efficient and make it as an urban catalyst;
It should maintain the function of a barrier to divide the downtown and midtown areas, giving them an obvious identification and avoiding gentrification.
Measures: Redeveloping the I45 into an urban green barrier, the upper surface is open green space and beneath it is an urban commercial and entertainment centre. The facade towards midtown is a natural view, and towards uptown is building view, which remains the identity of each area and attracts more people. (Fig. 2.7)



BIG-T AREA

Potential: As there is not enough space for open soil on the ground, there can be more green area, both above and under the ground;
Similarly, to make more space to walk, and with a basis of current tunnels, it has a potential for multi-layer space for people to walk and cars to drive;
Try to increase liveability.
Measures: Design a multi-level urban area and increase accessibility, walkability, vitality, liveability. (Fig. 2.8)

CONVENTION AREA

Potential: As the most active area in downtown, there is more potential and necessity to increase walkability; The other side of the highway is EaDo, which also has a great potential, make better connectivity with the area to make them have a better development together.
Measures: Change the local traffic pattern from the same level of grid traffic into a combination of loop and graded roads;
Creating a walking area combining with open public space;
Integrating more public transportation.

FUTURE HOUSING AREAS

Potential: These areas have the most potential for the development of modern high rise (apartment) buildings.
Measures: Build mixed-use residential areas that are predominantly residential and include other functions such as business, office, open green space, and parking.
As a high density construction area, except the traditional mixed use in plane, the mixed use can also be used in three-dimensional to make the building like a vertical city. In this way, avoid the lack of urban vitality in newly designed residential areas.
Therefore it comes to the concept of mosaic communities: mixed use both in plane and three-dimensional.
Fig. 2.9 shows the optimization from 2D mixed use to 3D mixed use, and the mosaic communities are used in those two areas.

Fig. 2.8 | Measures of Big- T area
Fig. 2.9 | Measures of future housing areas

Underground tunnel

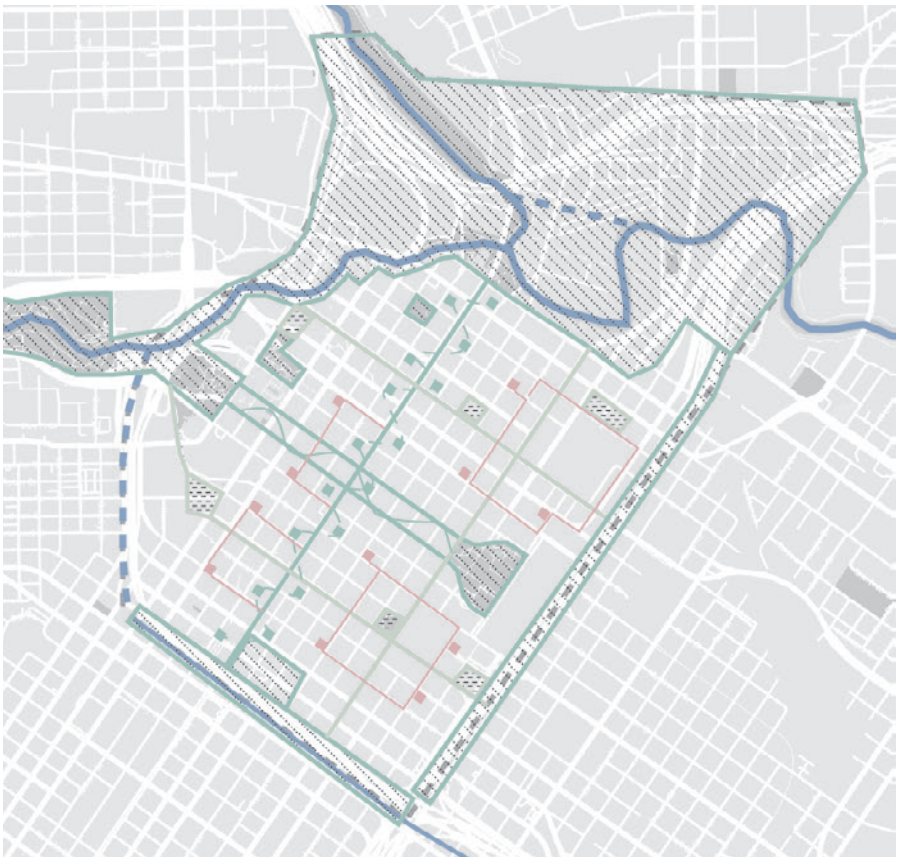
Sky corridor

Green space
Big T area
Future housing area
Convention area
Main green connection
Secondary green connection

Urban green space
District green space
Sky green space
Main green connection
Secondary green connection
Neighbourhood green space
Neighbourhood green connection
Water

Fig. 2.10 | Potential map for densify

Fig. 2.11 | Green and blue network



FOR WHOLE DOWNTOWN AREA

The strategy for the whole downtown area is to make a synergistic system of the sub areas, as shown in Fig.2.10. Different function areas act as different roles, but combining them together will turn into a better downtown.
Connecting green areas in the area as the structure of downtown which connects all the sub areas.
The big T area act as the secondary axis to connect downtown with the 4th ward neighbourhood and EaDo area.

GREEN & BLUE NETWORK

The green and blue network have a hierarchy and multilayers. (Fig.2.11) Containing four grades of green space - the city, area, neighbourhood and block green space. The green connection along Main St. is in the sky while along the secondary axis is on the ground level.

3 TIL- CONNECTIVITY

Public transport
Private traffic

Fig. 3.1 | Current highway layout

TRANSPORTATION

CURRENT SITUATION

Currently the road network as a whole lacks a hierarchy. The on and off ramps of the highways are connected directly with the local streets within downtown. The high flow highways therefor enter the low flow local Downtown streets without delay, thus creating capacity problems. These capacity problems result in traffic jams that will flow against the flow of traffic, and thus creating traffic jams throughout the entire highway network (Nagel et al, 2003). As Lewis Mumford rightly stated in his book The Urban Prospect: "Highway planners have yet to realize that these arteries must not be thrust into the delicate tissue of our cities; the blood they circulate must, rather, enter through an elaborate network of-minor blood vessels and capillaries" (Mumford, 1958). Figure 3.1 shows the current highway layout around Downtown Houston.

PUBLIC TRANSPORTATION SYSTEM

However, a lack of hierarchy within the road network alone does not account for all the observed traffic jams. Throughout the last sixty years Houston has been developed as a car-oriented society. As a result, the public transportation system is underrepresented. This can also be seen in the figures. In 2017 of the workers 16 and over 80.1% drove alone to work vs only 2.3% using public transportation (Census Reporter, 2019). The current public transportation network of Houston consists of 3 tramlines and a bus transit system. The majority of Houston is therefore dependent on the bus for public transportation. Current bus transportation is not that efficient, mainly due to the relatively close proximity of stops due to stop placing alone the line and close proximity of the bus lines themselves (Lowson, 2005). Figure 3.2 shows the current tramline layout and figure 3.3 the current bus transit system in Downtown Houston.

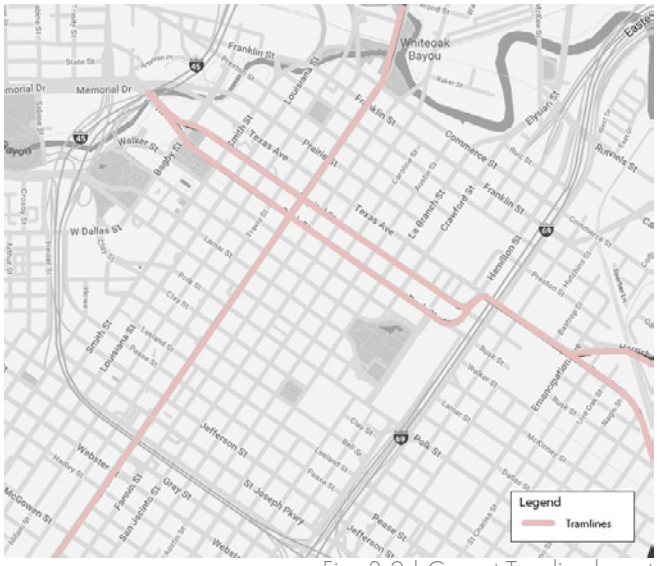


Fig. 3.2 | Current Tramline layout

Fig. 3.3 | Current bus transit system

Fig. 3.4 | Proposed Ringroad with detailed highway connection


Fig. 3.5 | Internal street layout

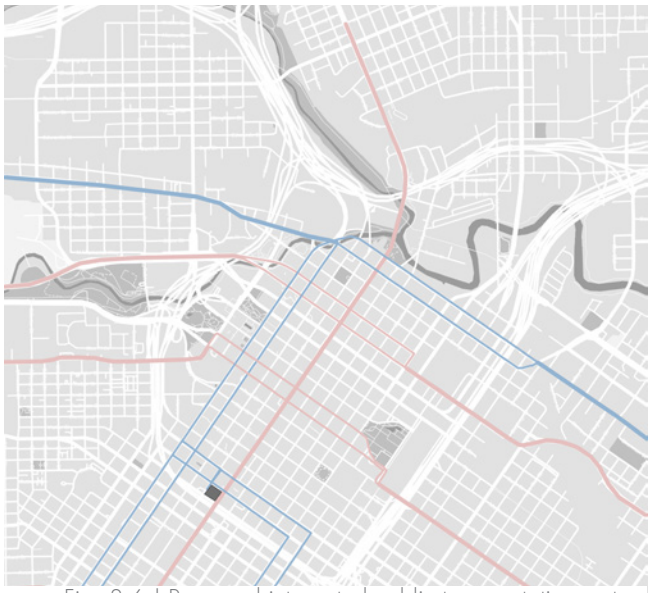


Fig. 3.6 | Proposed integrated public transportation system

SCENARIO 1

TOMMOROW SITUATION

To improve the overall transportation system of Downtown Houston three scenarios will be introduced. The first scenario will be a redesign of the current road layout, where through the introduction of hierarchy, the amount of car traffic can be reduced in the future housing areas. Secondly the first scenario will also feature a redesigned public transportation network with a more efficient layout and a lower travel time, thus resulting in a more interesting alternative to car travel. Figure 3.4 gives an overview of the proposed rind road with detailed highway connections.

ROAD NETWORK

Due to the nature of the grid structure traffic will follow the shortest possible path. This means that trough traffic is located in every street. To ensure the liveability of the downtown area and the future housing areas the negative effects of car traffic needs to be reduces. By creating a ring road structure, a hierarchy will be introduced to lessen the amount of trough traffic to the centre area. The ring road is designed in such a way that the I-10, I-45 and I-69 highways connect directly on the ring road. This will be lessening the negative effects of car traffic on the future housing areas and on the downtown area as a whole, thus increasing liveability. Lastly the internal grid structure needs to be redesigned to align with the new to be constructed ring road and area's outside downtown. The proposed inter street layout in figure 3.5 aligns with both the ring road and the downtown area. Only La Branch Street will have a split in the one-way traffic that is located at Green Discovery park. Figure 3.5 shows this internal street layout.

PUBLIC TRANSPORTATION SYSTEM

To increase the efficiency of the public transportation system the number of bus lines will be reduced. Currently the maximum walking distance is set at a quarter of a mile (1320 feet) (Hess, 2012). With a Downtown city block being 330 feet, this translates to a maximum of 4 Downtown city blocks. Also, by reducing the amount of bus lines within the downtown area the usage per line will be increased. The increased usage makes it viable to upgrade the bus lines to tramlines, thus increasing the capacity, reducing travel times and increasing the attractiveness of public transportation in general.
The newly designed public transportation system will feature 2 new tramlines and will extend the 2 existing tramlines. The remaining bus lines will all go to the Downtown Transit Center. The Downtown Transit Center itself will be restructured to act as a central station for Houston by being the central transport hub for both the bus lines as the tramlines. Figure 3.6 gives an overview of the proposed public transport system.

SCENARIO 2

MEDIUM TERM SITUATION

Fig. 3.7 | Street design with 2 remaining lanes of traffic
Fig. 3.8 | Street design with a cycle path

Currently one of the most vibrant locations of Downtown Houston is the Main Street. Here, green areas, different transport modes and mixed land use are combined, making sustainable transportation more attractive. The implementation of scenario 1 will invoke a lifestyle change. Due to the ring road and the increased usability of the public transportation system car usage within Downtown will be less. Therefore, the streets can be redesigned to reflect the changing lifestyles. Figure 3.7 shows the design with remaining lanes of traffic and figure 3.8 the new design with more space for cycling. The new street design will feature more space for walking, cycling and public transportation.

As the temperature can be quite high in Houston, more shadow spots are created. This will be done by planting trees or shadow creating constructions. In this way, it is more attractive to walk, and the liveability of this area is increased. Another solution is to increase walkability is to use tunnels. These tunnels are besides accessible for both pedestrians and cyclists. However, constructing tunnels can be expensive. Creating more shadow spots on street level can be favourable to this.

SCENARIO 3

FUTURE SITUATION

A part of the plan for downtown Houston is to develop new residential areas in order to increase the liveability in the area. However, a result of this development can be an increase in car usage in the area. To not let the amount increasing or let it decrease in the future, there is a need to develop alternative transportation modes.

In order to improve the traffic flow, decrease travel times, improve safety and liveability and save unnecessary costs in the area, intelligent transport services can be used. An example of such a transport service is Mobility as a Service (MaaS). Here, every kind of transport, both public and privately owned, is brought together into one mobile application. In this way, transport options from different providers can be combined and it possible to handle everything, from travel planning to payments, via this application (MaaS Global, 2016). This application can be used for the current public transport network, but also for new opportunities. An example of this is the possibility of sharing cars (CSA, 2018).

A current trend in the Smart City is sharing (public) goods and resources. With the help of ICT, a collaborative consumption, also called the sharing economy, has been developed. The key part of the sharing economy is to obtain, give or share the access to goods and services through online services. The more intensively use of resources can alleviate societal problems, such as pollution and hyper-consumption. In terms of transportation, it is nowadays more likely to share cars or bicycles. Car-sharing is a green mobility initiative which helps driving the sharing economy and creates a more sustainable environment. Furthermore, it is a way to use vehicles more intensively by using cars for multiple trips through the day instead of a single time for private use. Having access to a vehicle is more important than private possession, so less cars are needed (CSA, 2018; Katzev, 2003).

Developing an extensive car-sharing network can help to decrease car usage in the Downtown area. Hereby, it is important to not only look at Downtown area itself, but to the bigger area when developing this network. Because most of the people who are visiting Downtown are living outside this area. Developing this car-sharing network only in Downtown area will thus probably not lead to the desired outcome.

There are different types of car-sharing possible. First, a free-floating car-sharing network can be offered. Here, cars are parked on the street and are accessible for everyone by when using a mobile application. Within this way of car-sharing, the users can drive the vehicles among multiple stations or nodes to travel from one activity centre to another. With this type of system, trips are more likely to be one-way, because it is not needed to return the vehicle to the beginning point. It provides flexibility for the user, but complexity for the operator, because it is sometime necessary to relocate the vehicles in order to an efficiently operating system and to satisfy most users' travel demands (Barth & Shaheen, 2002). Since the surface of Houston as a whole city is very big, a car-sharing company needs to have enough vehicles or restrict the use to certain areas.

Another car-sharing system model is the model of the station cars. Here, the shared vehicles are located near public transport hubs, so commuters can use them on the home- and work-end of a trip. This type of car-sharing is mostly initiated by rail operators in order to reduce the parking shortages in the area close to the railway station and to increase the use of the train (Barth & Shaheen, 2002). Public transportation is not used that much at the moment, so it is less likely to implement this car-sharing system in Houston.

On a smaller scale, it is also possible is to have several cars per residential building. The people who are living in that building share the cars with each other, so they do not have to buy their own one. Reserving such a shared car can for example be done by using a MaaS application.

OVERVIEW TRANSPORTATION IN DOWNTOWN HOUSTON

This chapter gave an overview of the transport system in Downtown Houston. The area is very car-oriented; almost 50% of the surface is reserved for parking. Since there is no hierarchy in the road network, there are a lot of traffic jams during peak hours. This results in a capacity problem and thus delays. Furthermore, there is an extensive public transport network in the area, but this network is not very efficient. Because of these mentioned reasons, there can be said that there is room for improvement when talking about traffic. The goal of this design is to create a sustainable and efficient transport network in Downtown Houston.

Therefore, three different scenarios are designed. The first scenario is focusing on the redesign of the road layout. As mentioned above, there is no hierarchy in the current road layout. By implementing a more efficient layout, travel times can be decreased. The public transportation network is also redesigned. By lowering the amount of different lines and locating them close to important nodes, the efficiency is increased. The second scenario is focusing on the Main Street of Downtown Houston. This street is one of the most vivant streets in the area. However, there is not much space to cycle and to walk. By redesigning the street layout, more space can be created for these active modes of transportation. The third scenario is also focusing on the transition towards more sustainable transportation. This is done by introducing the concept of Mobility as a Service (MaaS) and the possibility of sharing cars in Downtown Houston. With these three scenarios, there is tried to implement a more sustainable transport network which is less car-oriented and more focusing on active modes of transportation. There should be noted that this cannot be implemented immediately since the inhabitants of Houston are very attached to having their own private vehicle. Life styles should be changed when implementing this, so it is more a long-term vision.

4 DESIGN RESULT - RESILIENT

Modular housing
Ring ring
Ring route
Main Street

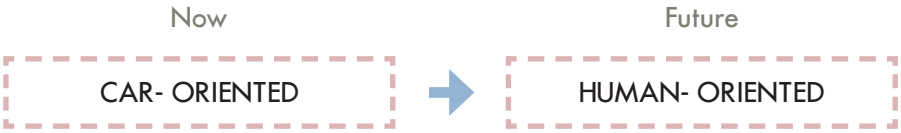


Fig. 4.2 | Paradigm change

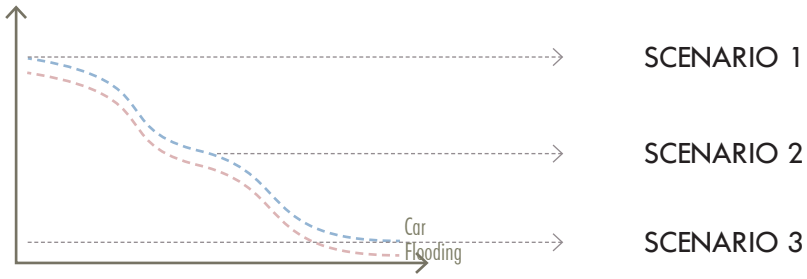


Fig. 4.3 | 3 scenarios

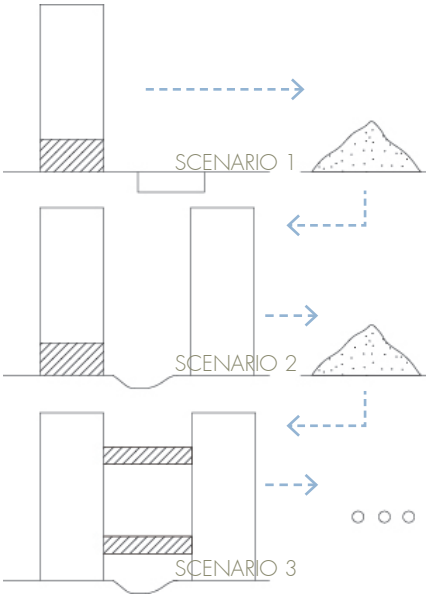


Fig. 4.4 | Construction waste to different scenarios

CONCEPT

RESILIENT

CONFLICT

Houston is suffering a serious flooding issue, and the situation will get even worse because of climate change. Meanwhile, the lifestyle of Houstonians is totally car oriented which aggravates climate change. The lifestyle, on the other hand, affects the paradigm of urban development

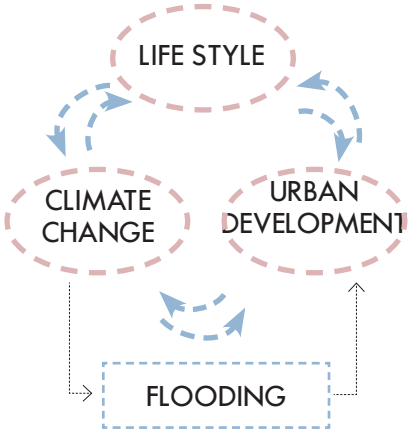


Fig. 4.1 | Integrated system

which is car oriented scale, and it makes people use cars more and makes more serious climate change, more flooding. Finally, it damages the urban development. This comes to a vicious circle, makes it a conflict that people's lifestyle is damaging the urban environment. (Fig. 4.1)

CHANGE OF LIFESTYLE

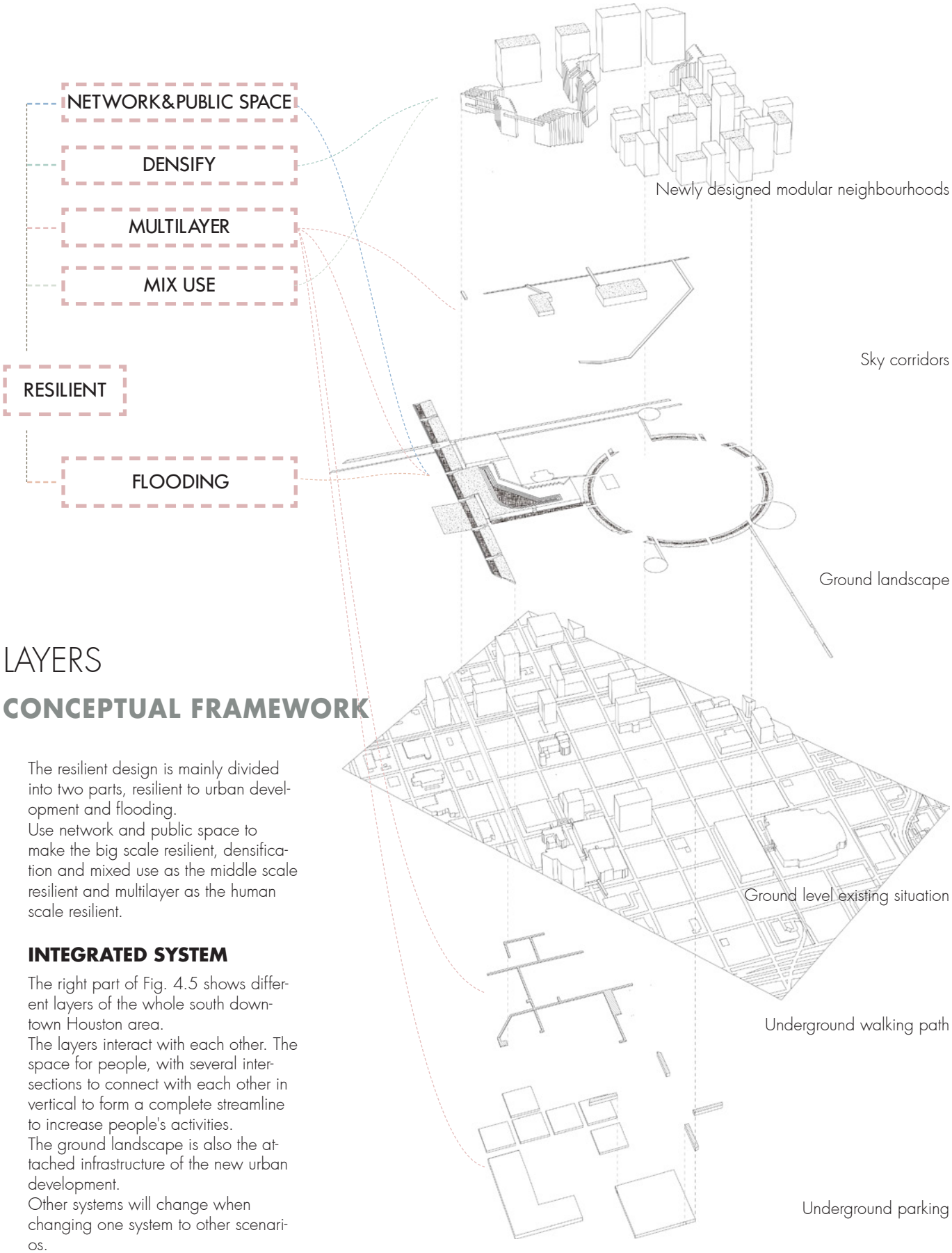
Therefore, the design starts with the change of lifestyle from current car-oriented to a future human-oriented mode. (Fig. 4.2) The change in lifestyle will definitely change the paradigm of urban development.

SCENARIOS

Changing need time, in different phasing there will be different paradigms of urban development. In this design, it is divided into three scenarios, the recent scenario, mid term scenario and future scenario. (Fig. 4.3)
The main characters affected by changing of lifestyle is car usage and flooding. As time goes and lifestyle changing there will be fewer cars and less flooding.

RESILIENT

As the paradigm of urban development is changing, with the traditional construction way, there will be a new building designed to adapt to different scenarios, and for the following ones, the buildings are demolished and built a new one instead, which makes a big construction waste. (Fig. 4.4) Therefore, making a resilient design to adapt all the scenarios is necessary.



LAYERS

CONCEPTUAL FRAMEWORK

The resilient design is mainly divided into two parts, resilient to urban development and flooding.
Use network and public space to make the big scale resilient, densification and mixed use as the middle scale resilient and multilayer as the human scale resilient.

INTEGRATED SYSTEM

The right part of Fig. 4.5 shows different layers of the whole south downtown Houston area.
The layers interact with each other. The space for people, with several intersections to connect with each other in vertical to form a complete streamline to increase people's activities.
The ground landscape is also the attached infrastructure of the new urban development.
Other systems will change when changing one system to other scenarios.

Fig. 4.5 | Explosion drawing of different systems




CONTEXT ANALYSIS

EXISTING SITUATION& PROBLEM STATEMENT

Fig. 4.6 | Current land use
Fig. 4.7 | Contour line & overflow
Fig. 4.8 | Traffic & parking
Fig. 4.9 | Green space

Green space
Big T area
Future housing area
Convention area
Main green connection
Flooding area
Green barrier
Commercial looking
Landscape looking
High line
Public space

LAND USE

The current land use in south downtown Houston is not efficient, except the St. Joseph Medical Centre and Toyota Centre, there are only several separated residential housing, office building and some small scale commercials. There are also a lot of ground parking place and parking garages. The small scale commercials and the empty site can be easily redeveloped. The ground parking area can be regenerated after arranging the car parking into vertical parking garages while remaining the existing parking garages.
The high rises with the function of living and office are remained but can be regenerated by adding green roofs, sky corridors, green facade, etc. (Fig. 4.6)

HEIGHT & FLOODING

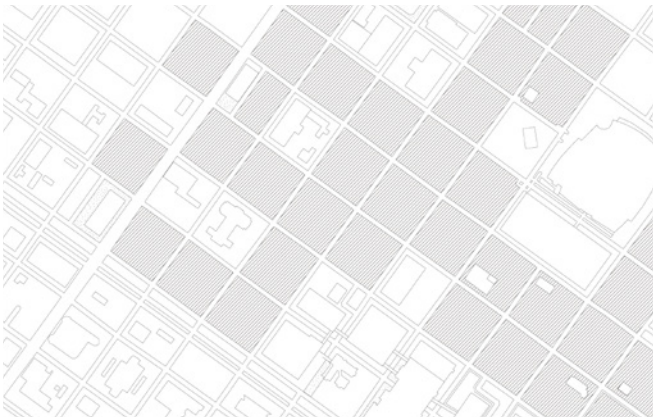
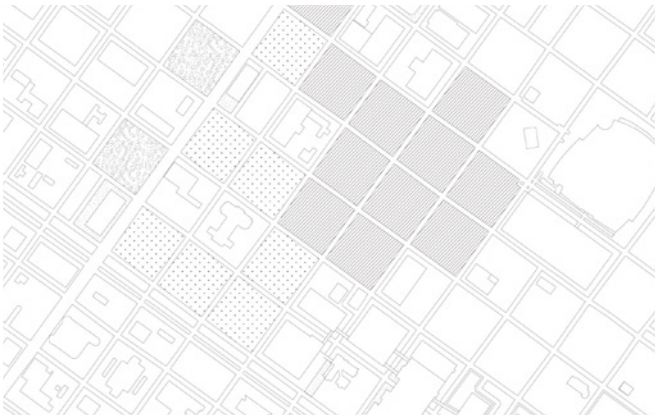
The whole Houston is almost flat which causes the water can not flow quickly outwards the urban area, however, there is still a small difference in height, as the contour lines in Fig. 4.7 shown.
When there is heavy rain, it will be an overflow near the I45 highway area. (Fig.4.7) In general, the flooding issue is not so serious in the downtown Houston area.

TRAFFIC & PARKING

The high way I45 in this area is going to be removed and build a green barrier between downtown and midtown instead. There is a tram line along the Main Street and the other streets are in the same hierarchy, and one direction, which makes the grid traffic network.
Ground parking and parking garages cover most of this area. (Fig.4.8)

GREEN SPACE

There is only little green space in this area, a sports park near the Toyota Centre, a park around the church and one in the Medical Centre, and they are all separated with no network.
Along the street, there is also little green space and the street life is monotonous. (Fig.4.9)

OPPORTUNITIES

HUMAN ORIENTED & RESILIENT

DENSIFY

There are a lot of small scale commercials, the empty site and ground parking space, which are easy to redevelop. (Fig.4.10)
The mode of overspread urban development is not fit for a sustainable and human oriented future.
Therefore, it is necessary to change into a concentration mode of urban development and the south downtown Houston area has the best potential for redevelopment at a low cost, low demolishment and high benefits.

MIXED USE

The downtown Houston now is an area with a single function in each sub areas as shown in Fig.4.11, such as the office area and the convention area. Therefore, when it is weekend or there is no game and conventions, there are no people using the urban environment, and even it is under used, the street life is lack of vitality. These are partly caused by the single function plan.

In the future, when redeveloping the area into a mainly residential area, it is also important to make it mixed used to keep the urban vitality.

WATER FLOW

As there is a highest point in the area and second highest points around, the water has a trend to flow towards the lowest part and form a ring area around the highest part. (Fig.4.12) Because the height difference is not big enough to flow the storm water, it is necessary to make artificial dig to enhance this potential.

GREEN NETWORK

Following the strategy for whole downtown Houston, there are three hierarchies of green space, the urban scale space(green barrier), main green corridors; the middle scale space(the parks); and the neighbourhood scale green space, neighbourhood green ways which link to the main green network. (Fig.4.13)

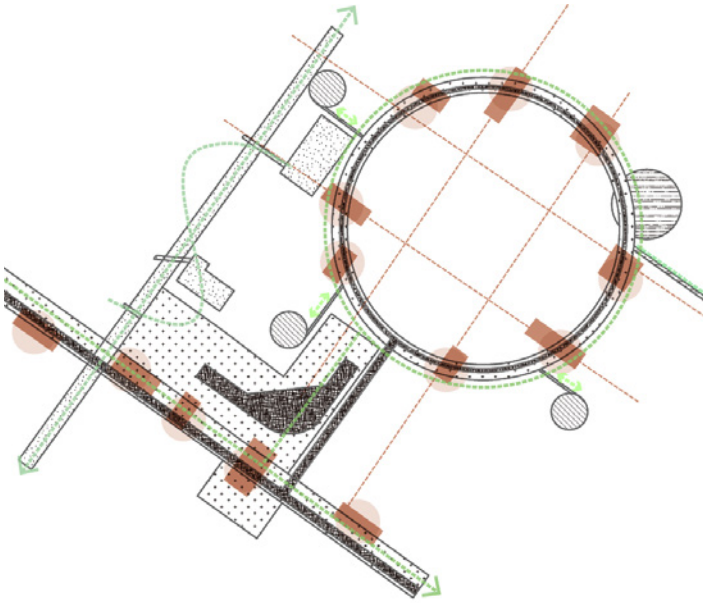
Fig. 4.10 | Potential map for densify
Fig. 4.11 | Mixed function
Fig. 4.12 | Water flow direction
Fig. 4.13 | Green network

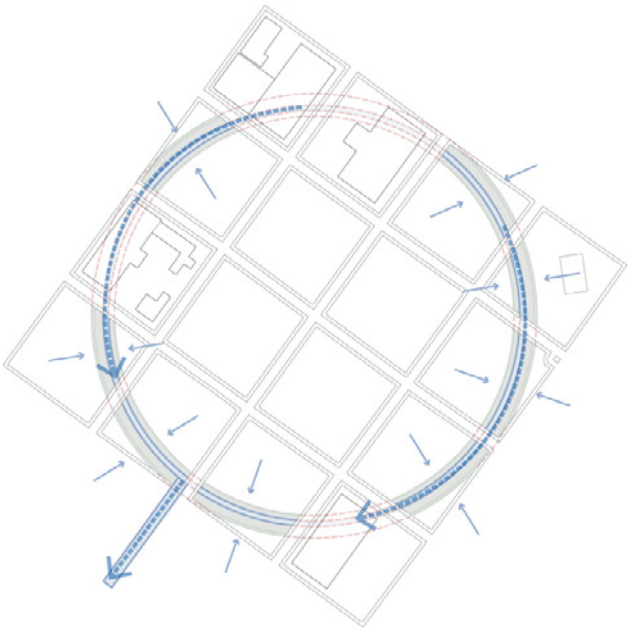
Potential point

More social housing
More residential housing
More office

Direction of water flow

Urban green space
Sky green space
Water
Main green connection
Sky green connection
Neighbourhood green connection





RESILIENT I

NETWORK & PUBLIC SPACE

Fig. 4.14 | Ring in the whole network
Fig. 4.15 | The water ring

New building
Roof garden on high rise
Rain route
Roof garden
Green corridor
Rain ring
Underground rain route
Corridor
Undergroung tunnel
Undergroung tunnel

Following the strategy for the whole downtown Houston network, there are three hierarchies of green space and green space on different height level. Keep the topology of network unchanged, add the characteristic in site. (Fig.4.14) And the network can be adaptable to different scenarios and the flooding.

WHY USING THE RING

There are mainly four reasons why using the shape of a ring.

- the existing height situation

There is a highest point in the area and second highest points around, the water has a trend to flow towards the lowest part and form a ring area around the highest part. (Fig.4.15)

- the fluent flow of water

As this route is the infrastructure that directs water flow, it is easier for water to flow in a curve than in a right angle.
During the water flow, if there is a slow down area, it will be more likely to be flooded. Therefore, use the shape of the ring, where there is no angle so water can flow directly away.

- neighbourhood identity

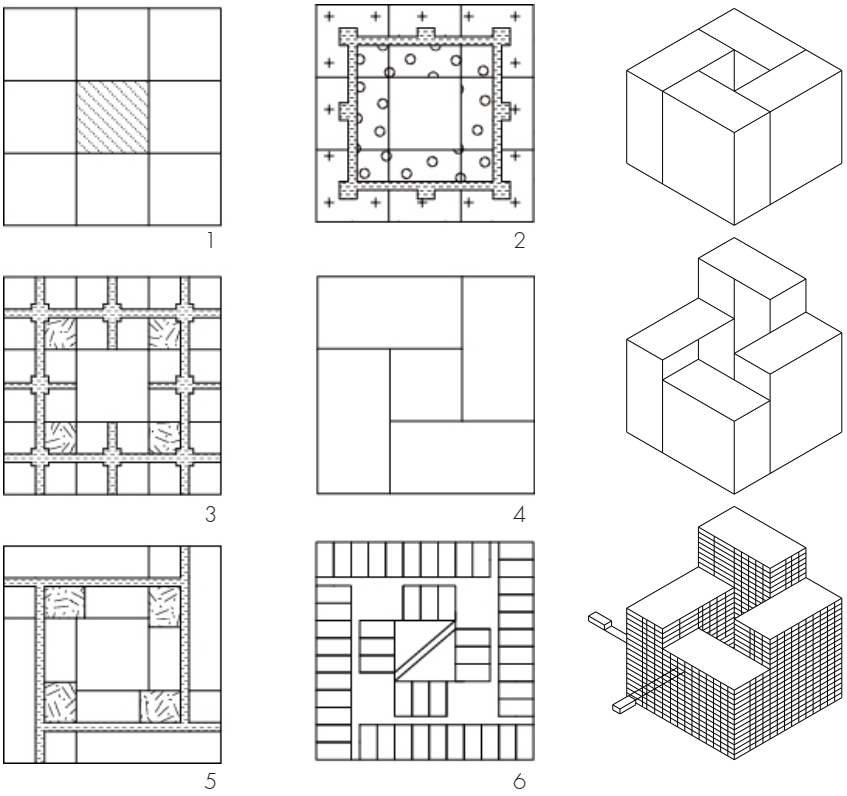
It will be better to make a visible boundary but accessible for all the people to make them have an identity of the living environment and a small functional barrier between different areas.

- respond to landmark

In this area, the Toyota Centre as the landmark and also the urban catalyst, it has a shape of an approximate circle. It will not be strange if put the ring beside it.

PUBLIC SPACE

Amplify part of the green barrier to be a roof park linking the two sides of the green barrier. As a slope landscape, people can use the roof park.
Along the ring, people can also have lots of kinds of public activities, such as sports fields, skate parks, picnic areas, outdoor concert hall, water squares, social communication space (chess, card games), square dance, etc.



RESILIENT II

DENSIFY

In order to make the urban development more sustainable, it is reasonable to make a concentrated urban development to decrease the amount and the distance of car usage.
Therefore, in this design, there is densification in Downtown Houston, mainly residential function, and with the other mixed functions such as office, commercial, entertainment, etc.

MODULAR HOUSING

In order to make the densification resilient to the different scenarios, use the modular housing concept. (more details on the next page)

SQUARE IN RING

The first project near the Toyota Centre, at the highest point of the area, is named Square in Ring. As the existing situation of this area is mostly empty lots and ground parking, there is not so much limitation. Therefore, continue to use the grid (square) texture of the city, and adapt the square community to the circular Rain Ring.
To put the modular housing framework into Houston grid, the block is divided into 9 units (Fig. 4.16-1) and ensure that each unit can communicate with each other (Fig. 4.16-2), with the necessary traffic space and ensure the consistency of the module size, it comes to the plan in Fig.4.16- 3. However, in this case, the proportion of traffic space is too large, which is not profit efficient. And there are some corners that the modules can not move freely.
In order to avoid these problems and make it more profitable. Finally, it comes to divide the block into four units, as shown in Fig.4.16- 4. Add the traffic space and share space as shown in Fig.4.16- 5, and the plan is as shown in Fig.4.16- 6, with the modules in.
To form a cluster of buildings, each unit can have a different height to reduce the occlusion of sunlight between each other, increase the use of the roof garden, and make the city skyline look more interesting. (Fig.4.17)

Fig. 4.16 | Plan of modular housing
Fig. 4.17 | Building block 1

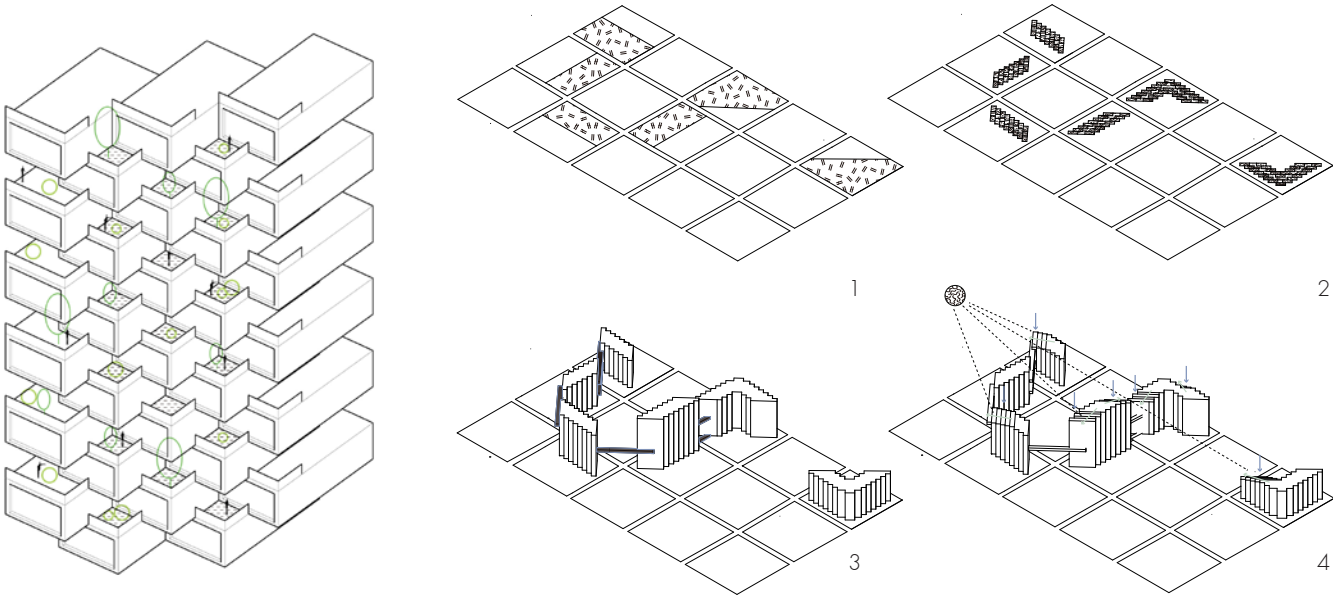


Fig. 4.18 | Yard on the unit
Fig. 4.19 | Design process

SKY YARD

The second neighbourhood near the main street and the rain route is called Sky Yard. The common life style of Houstonians is living with there own yards. Different from the Square in Ring, this project is built mainly for residential instead of social housing. Therefore, it has a higher demand for high quality living environment. In order to meet these conditions, the project is located on one side of the main road, which means to have an excellent traffic condition, and is also close to the Rain Route park, which means to have a good natural environment. What's more, we hope to further improve the quality of life by adding private yards.
In order to form private yards through the same module as used in Square in Ring, through the up, down and left, right movements, the roof of each unit is used to form a garden for upstairs. (Fig. 4.18)
The design process of Sky Yard is shown in Fig. 4.19.
First, statistics on the status of land use, identify areas where construction is possible. (Fig. 4.19-1) Design the detailed plan on site considering the movement of the modules. (Fig. 4.19-2)
Give different heights to different buildings to make them in a whole looks like a natural mountain with the trees in yards, to optimize urban landscapes and skylines and the blocks are linked by sky corridors to increase connection and communication between different buildings. (Fig. 4.19-3)
In order to reduce the occlusion of sunlight between each other, increase the use of the roof garden, make the outline more like a natural mountain, let different parts of the building also have different heights. (Fig. 4.19-4)

Both of the Square in Ring neighbourhood and the Sky Yard neighbourhood are built in the way of modular housing, which will be resilient to adapt to the future changes. The design also takes the living experience of people into account, increasing the possibility of walking and communication within the neighbourhoods.

MODULAR HOUSING

STRUCTURE

Modular housings are prefabricated buildings that consist of repeated sections called modules.[1]
It can be well fitted to the resilience demand, because when the scenario change, modular buildings can be disassembled and the modules relocated or refurbished for their next use reducing the demand for raw materials and minimizing the amount of energy expended to create a building to meet the new need.
In this design, the first step of construction only contains the structure and infrastructure(such as pipes, water filter, water storage and pump), the modules are then moved here by the owner and can be moved to other places to adapt to the scenario changes or the owners' movement. Therefore, the owner of modules can buy or rent the right to use the structure and can easily move their modules. The detailed design is shown in Fig. 4.20.
In some of the layers, the four units can also be linked by a sky corridor, as shown in Fig. 4.21. People can go inside the corridor and on the top of the corridor is the water infiltration, filter and storage facilities.

[1]Lacey, Andrew William; Chen, Wensu; Hao, Hong; Bi, Kaiming (2018). "Structural Response of Modular Buildings – An Overview". Journal of Building Engineering. 16: 45–56. doi:10.1016/j.jobe.2017.12.008

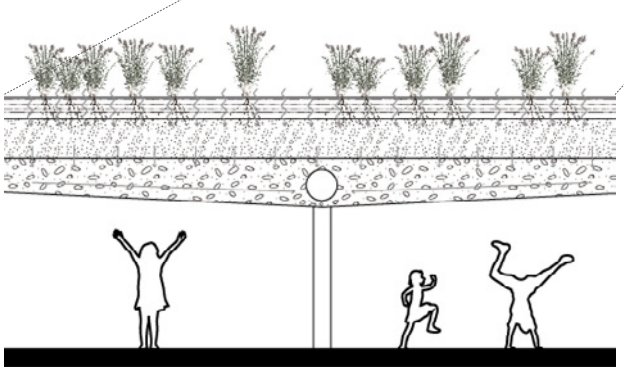

Top layer soil


Infiltration layer soil


Filter layer soil

Fig. 4.20 | Explosion drawing of modular housing

Fig. 4.21 | Section of sky corridor



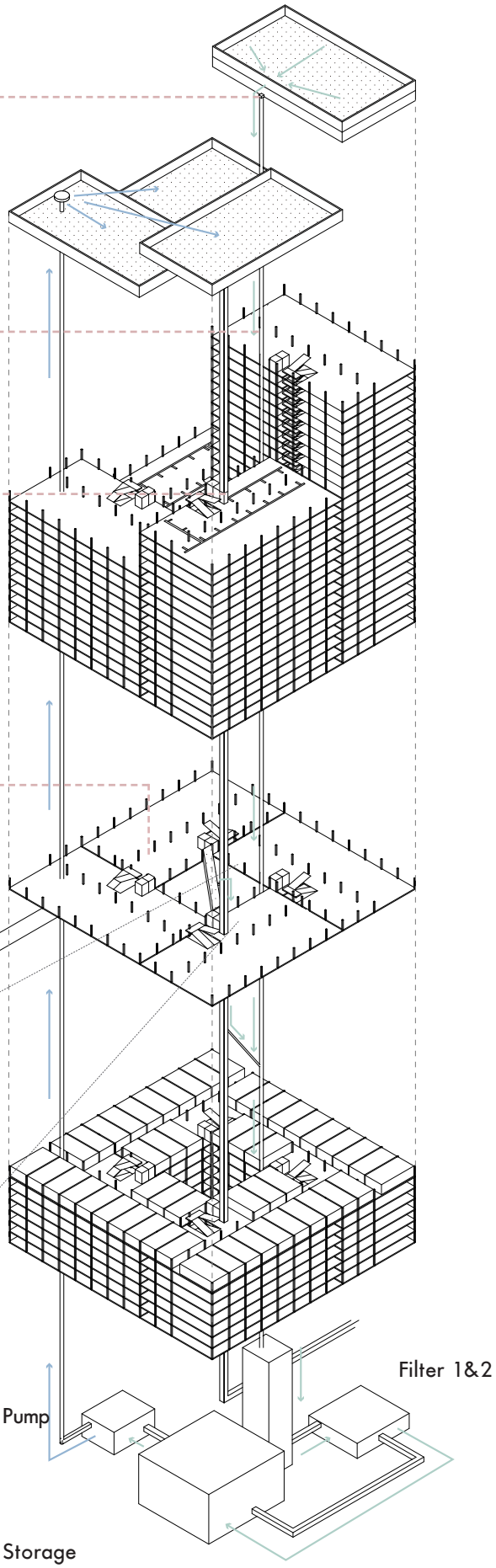
Roof garden
On the top of the roof is the roof garden, which can infiltrate and filter the rainfall, and also decrease the urban heat island effect.

Water recycle
The water is first filtered by the plants and then cleaned by filters, storaged in the base of building and use again for watering the green.

Pipe shaft
Pipes in each unit are arranged in one pipe shaft and divert to each room in each floor.

Frame structure
The frame is designed that every module can be put in and moved out easily.

Modular unit
The scale of each module is 6m*12m*3.6m. Multiple modules can be combined.



RESILIENT III

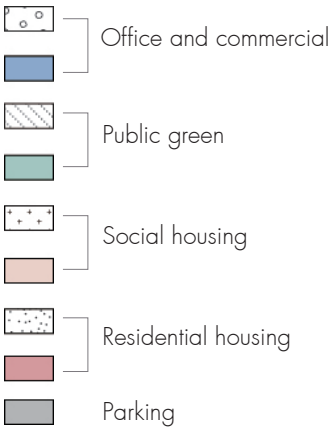
MIXED USE

The main function of modular housing is residential, contains regular housing and social housing. For social it is enough to use one module, and if it is too small for the owner to only have one module, they can combine two or three modules horizontal and vertical. To avoid the situation that no people use it except sleeping, add multiple functions to the living towers, such as public green, office, paring and commercial. The office and commercial are also the same modules but could combine more. The public green can just use the empty frames to build public green areas.
As the modules can be moved easily, the functions of one building can be continuously changing adapted to the change of scenarios. However, it should always keep mixed used.

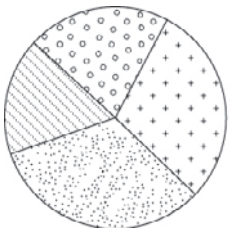
CHANGE OF FUNCTION

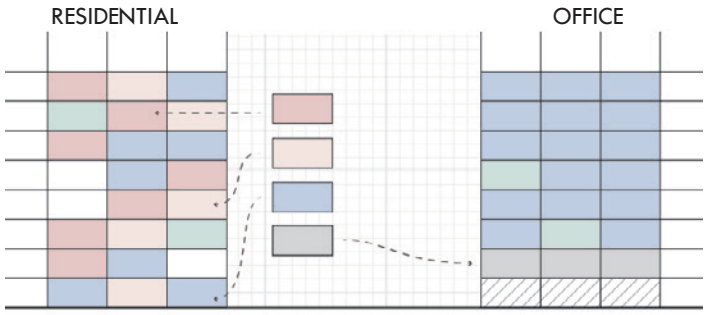
To adapt to the scenarios, there are some regulations of the occupy and changing of functions. (Fig.4.22)
For scenario 1, the living, office, commercial modules are put into the residential towers, the first several floors of office towers are remained empty for flooding or as the parking garage.
For scenario 2, some commercial functions start to move to the first several floors of office buildings, as there is less flooding. The places change to be empty can be room for public green or other new modules.
For scenario 3, under the efforts of managing flooding and reducing cars, more commercial modules can be moved to the first floors of office buildings, where people can experience again the vitality of street life.

Fig. 4.22 | Scenarios of function and construction progress

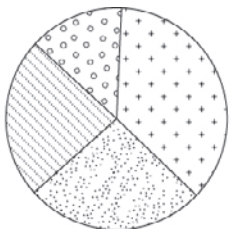


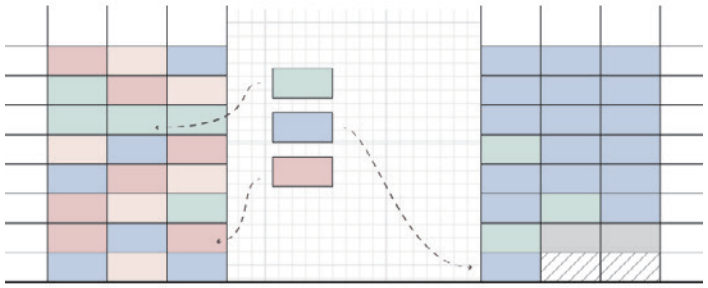
SCENARIO 1



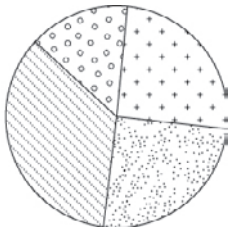


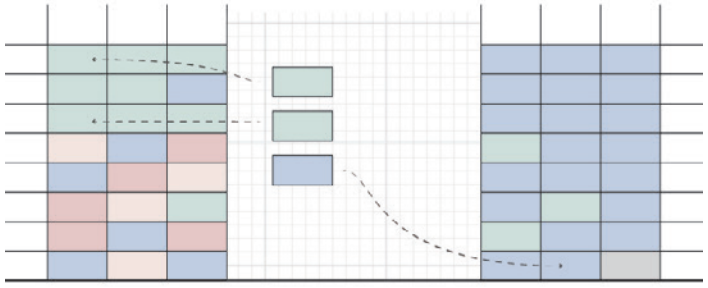
SCENARIO 2

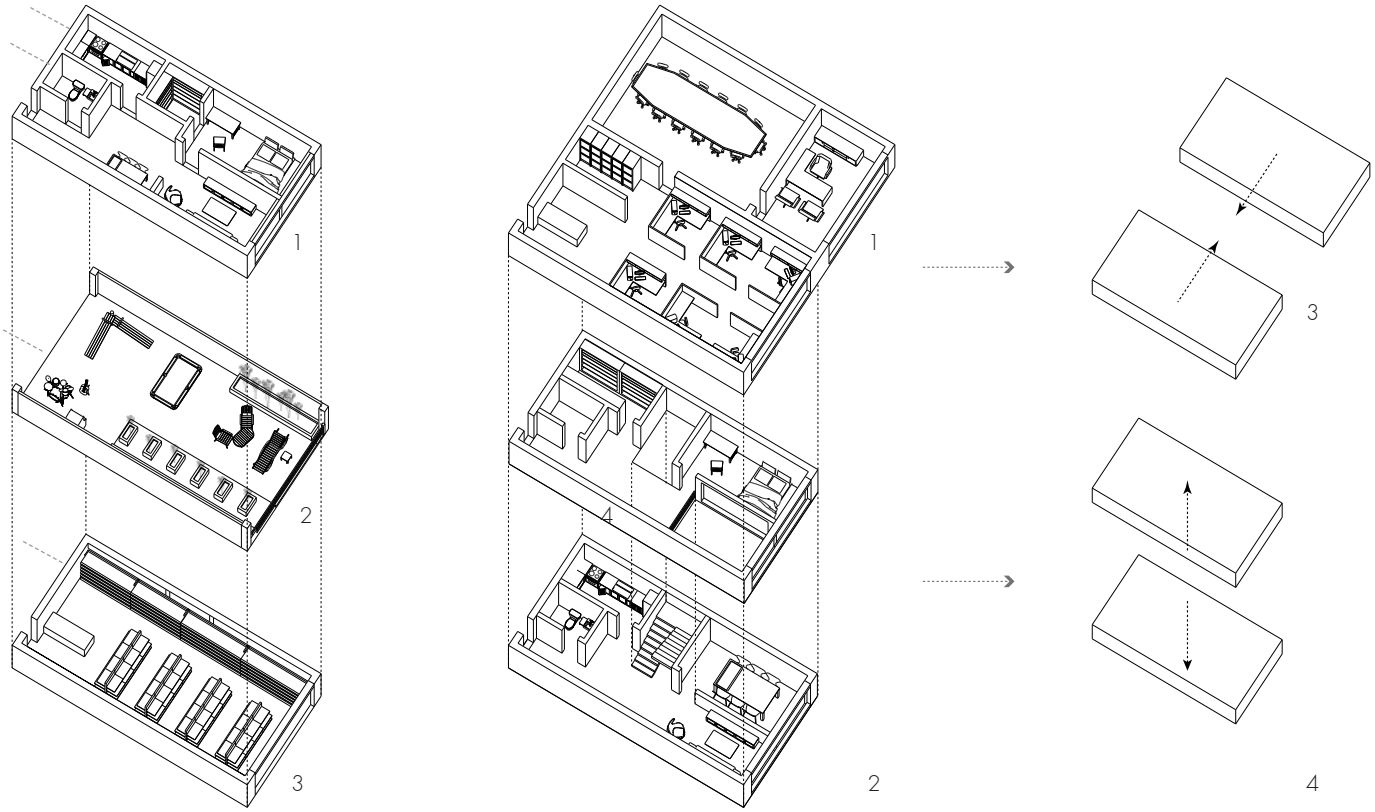




SCENARIO 3







INTERIOR LAYOUT

The drawing Fig. 4.23 shows the basic interior layout of a single module, with different functions. Fig. 4.23-1 shows the interior of a social housing; Fig. 4.23-2 shows the public area, that people can share the green area to plant and have entertainments; Fig. 4.23-3 shows the possibility of other functions like a small shop. These drawings show the possible examples of how to use the modules, while the owner of them have a great autonomy to decide how to use them.
Each module has a fixed pipe interface, and the facilities inside the module can be arranged at will, only to ensure that the interface can be connected with the connection from the pipe shaft.

MODULE COMBINATION

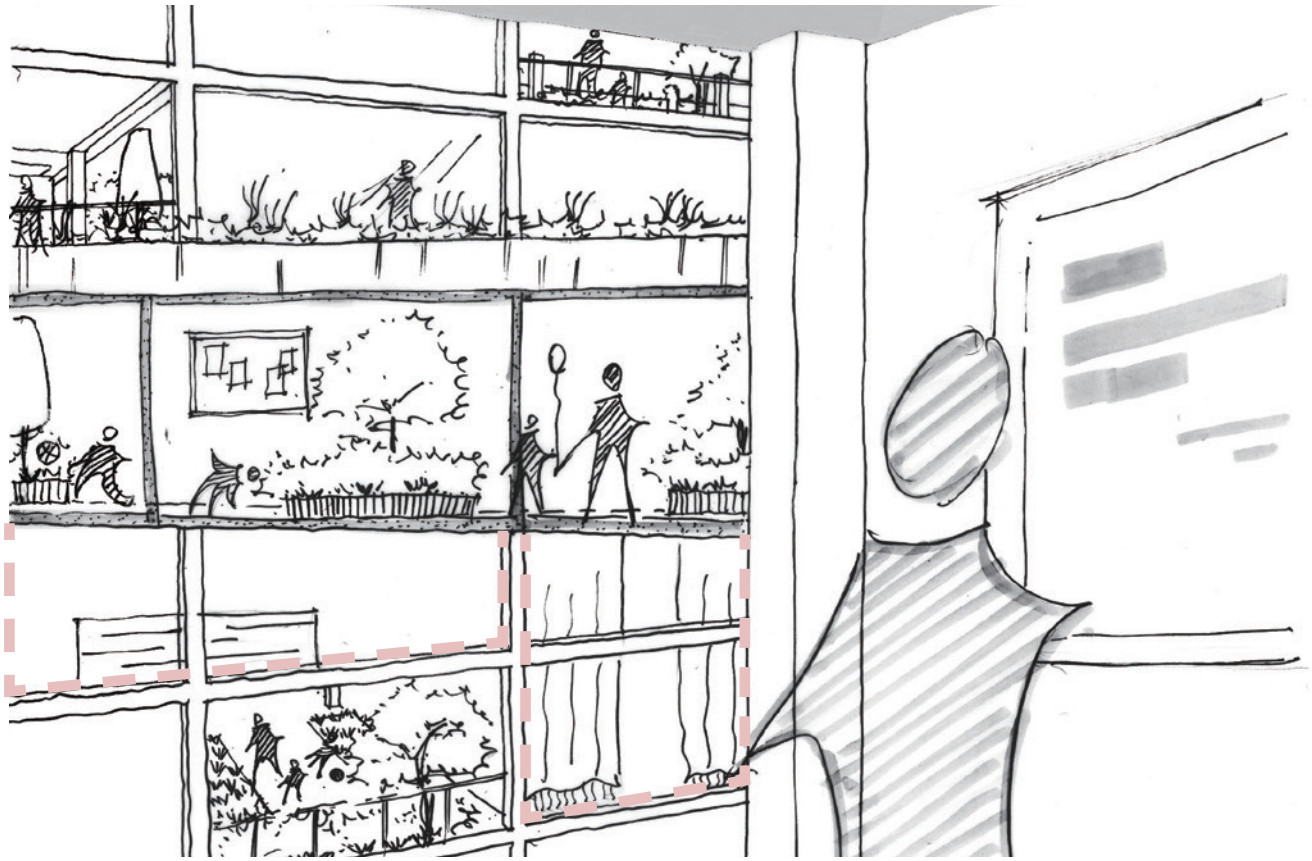
As shown in Fig 4.24, the modules can not only use singly but also combined. Theoretically, it can combine as many as needed. Here are two examples of combine two modules which are adjacent on the same floor (Fig. 4.24-3) and in the same location but on two adjacent two floors (Fig. 4.24-4).

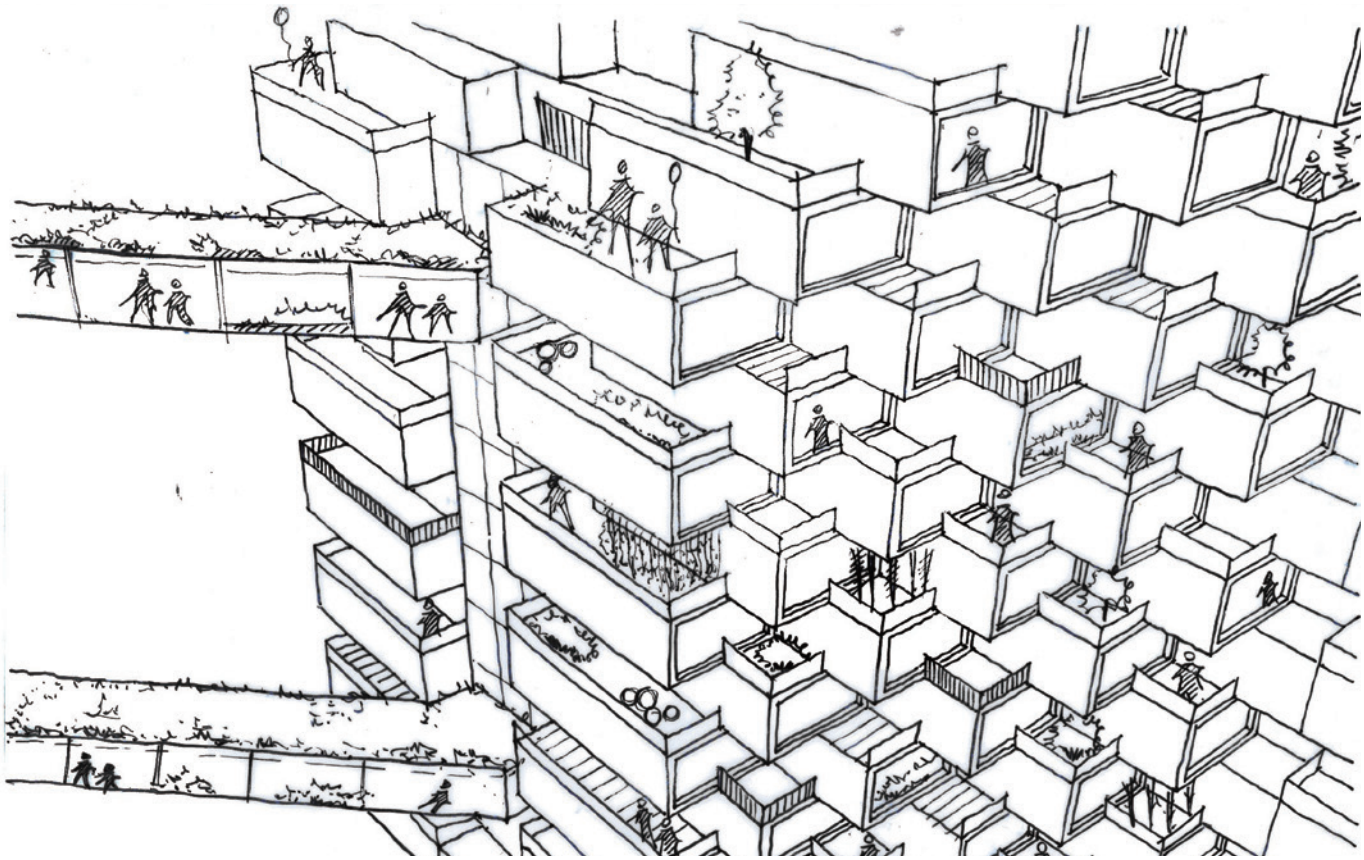
The Fig. 4.24-1 shows the combination of two modules on the same floor and used as an office; The Fig. 4.24-2 shows the combination of two modules on different floors and with the residential function.

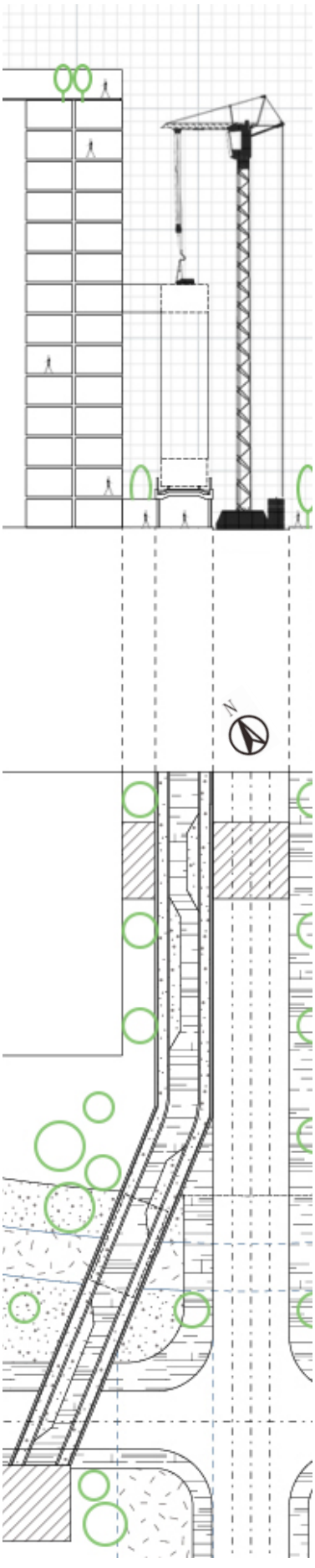
LIVING EXPERIENCE

Fig. 4.25 shows the living experience of Square in Ring. This drawing is a scene when people stand in the share space and look inside the courtyard. They can see people on the corridor and other public spaces are being used. The part that is framed by pink squares indicates the effect of combining multiple modules.
Fig. 4.26 shows the living experience of Sky Yard. The yards are being used by alternative functions, which makes the building have an abundant living experience, the connection by the corridor transfers the increasing private activities into an overall increase of neighbourhood vitality.

Fig. 4.23 | Interior layout of module
Fig. 4.24 | module combination
Fig. 4.25 | Perspective of Square in Ring
Fig. 4.26 | Perspective of Sky Yard







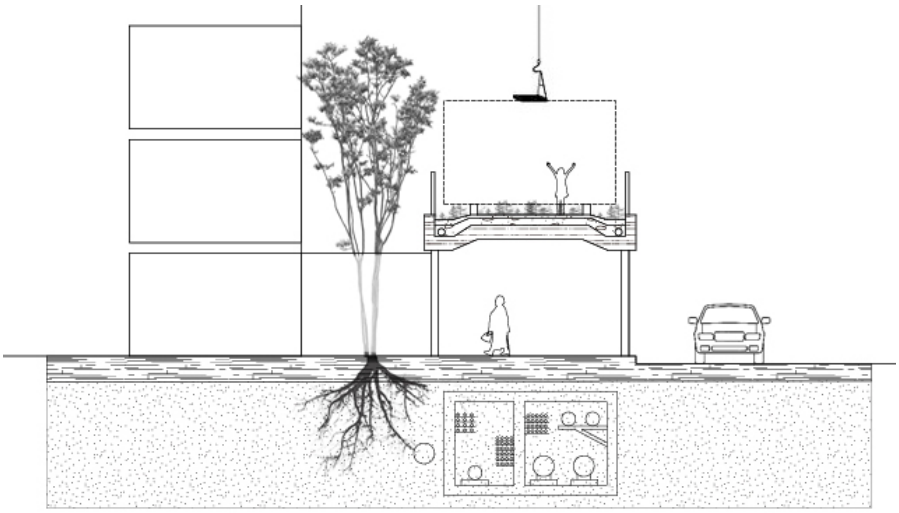


Fig. 4.27 | Plan & section of connector
Fig. 4.28 | Detail section of connector

HOW TO BE RESILIENT?

To be adaptable to different scenarios, the modules are moved according to changing demands. Therefore, the way how to reuse the modules in changing scenarios means how can this system be resilient.

CONNECTOR

Use the connector to connect the modular living tower and modular office tower, by which the modules can be transferred. There is specific space along with the connector for the crane to put in and pull out the modules as shown in Fig. 4.27.
In the living tower area, the connector is 7 meters wide, the modules can be transferred on the top of it. While there are no modules transferred, it can act as a highline part, meanwhile, manage the rain water. Under the connector, there is also an indoor space for people to walking in, in order to deal with the hot weather. (Fig.4.28)
In the office tower area, there is not enough space to place such a wide connector, therefore, the modules are transferred on the side of the connector, as shown in Fig. 4.43. while the other parts are the same.
The connector also act as the role to remind people of aware the changes in lifestyle. To give them an identity of living in a circular neighbourhood, and as a pilot project, show visitors this construction model and let more people aware that they can change to a more human oriented lifestyle.

Connector
Open soil
Area for crane
Water

Infiltration layer
Filter layer
Artificial surface
Clay

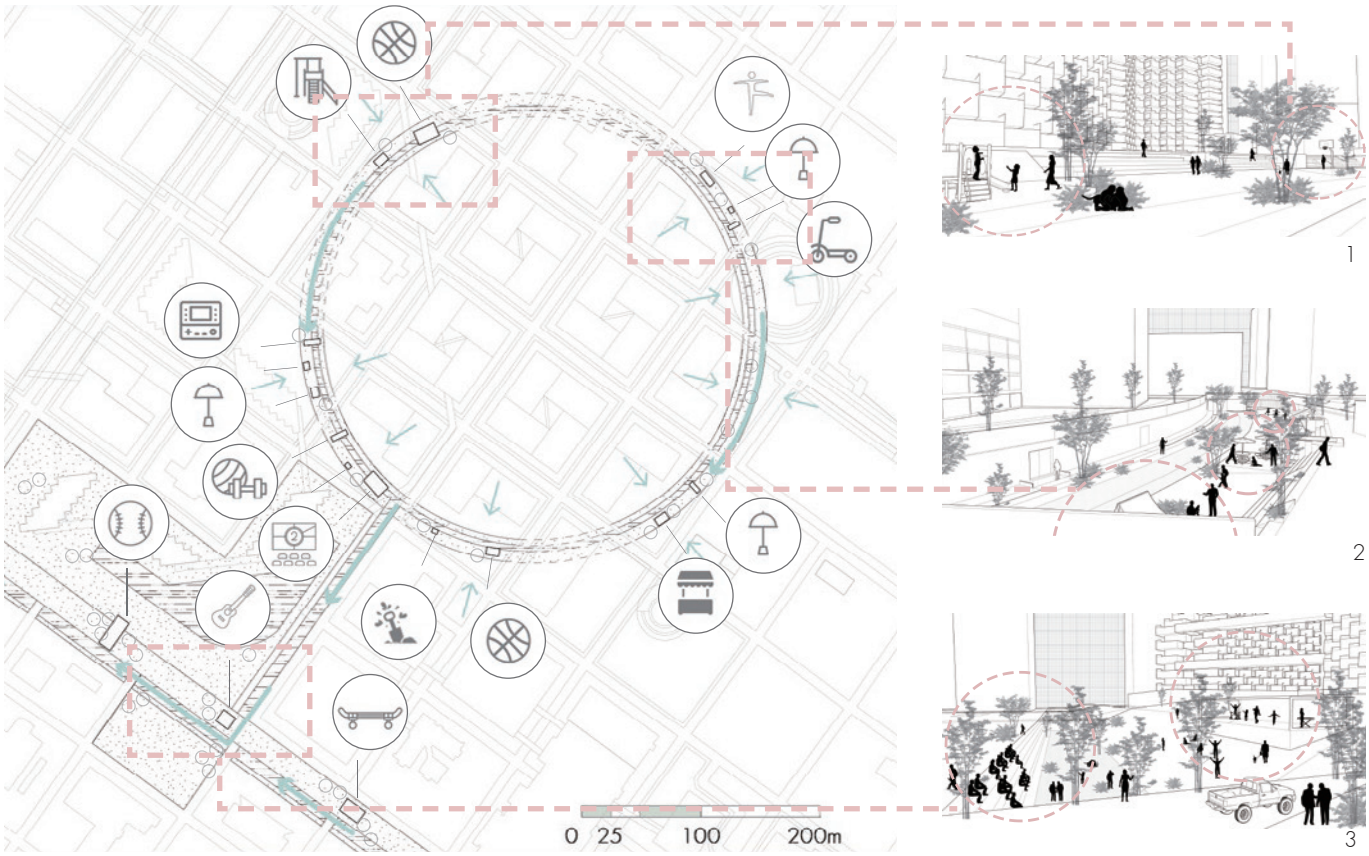


Fig. 4.29 | Plan of water resilient design
Fig. 4.30 | Eye level perspective
Fig. 4.31 | Case: Dakpark Rotterdam

RESILIENT IV
FLOODING

In Houston, as climate change becomes more and more serious, there will be more and more rain fall in the future, as the small amount of open soil and flat landscape are hard to change, it is urgent to find a way to make a water resilient design, to fight with the increasing flooding.
To be adaptable to the changing scenarios, use the flooding resilient design which mainly contains two parts: the Rain Ring and the Ring Route. (Fig. 4.29)
Make ditches in these two parts to let rain water flow into it and flow along the ring/ route towards the Bayou, and increase the water infiltration and storage during this process. In this way, decrease the direct overflow to Bayou area.

EYE LEVEL EXPERIENCE

As Fig. 4.30 shown, the Rain ring and Ring Route are also important public space. People can have different activities according to different features of the landscape.
The Ring Route project learns from the case of Rotterdam dakpark. (Fig. 4.31)

Resource: https://www.rotterdamarchitectuurprijs.nl/2014/dakpark.html
https://azua.nl/wp-content/uploads/2016/10/2013x_SKM5229w3.jpg
https://www.architectuur.nl/nieuws/dakpark-rotterdam-zoekt-bouwtalent/

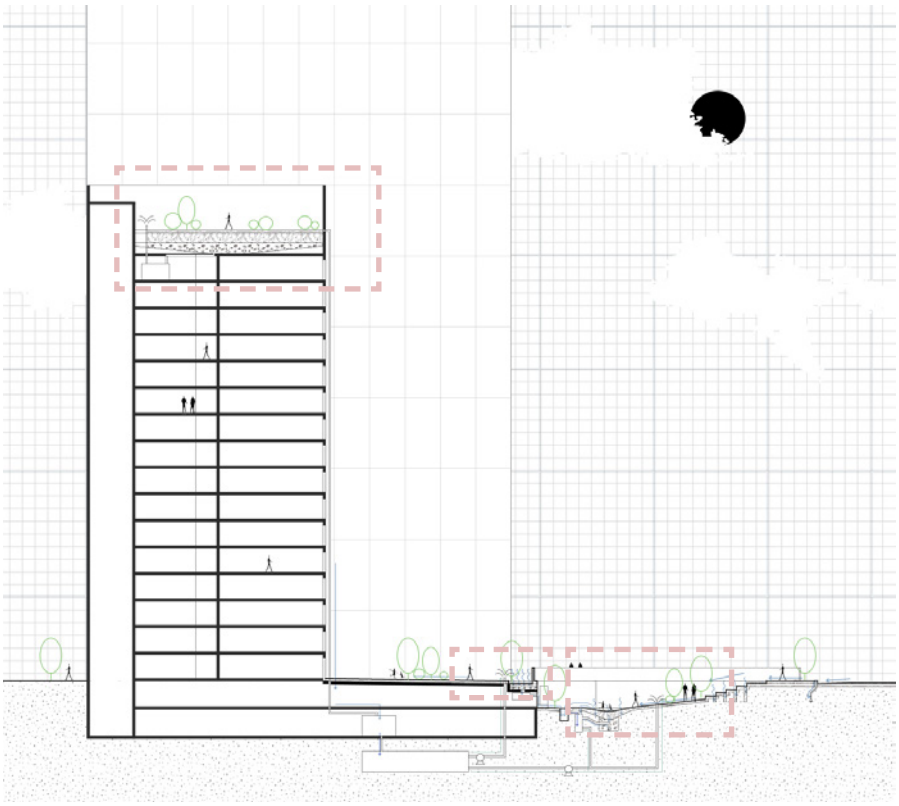
RAIN RING

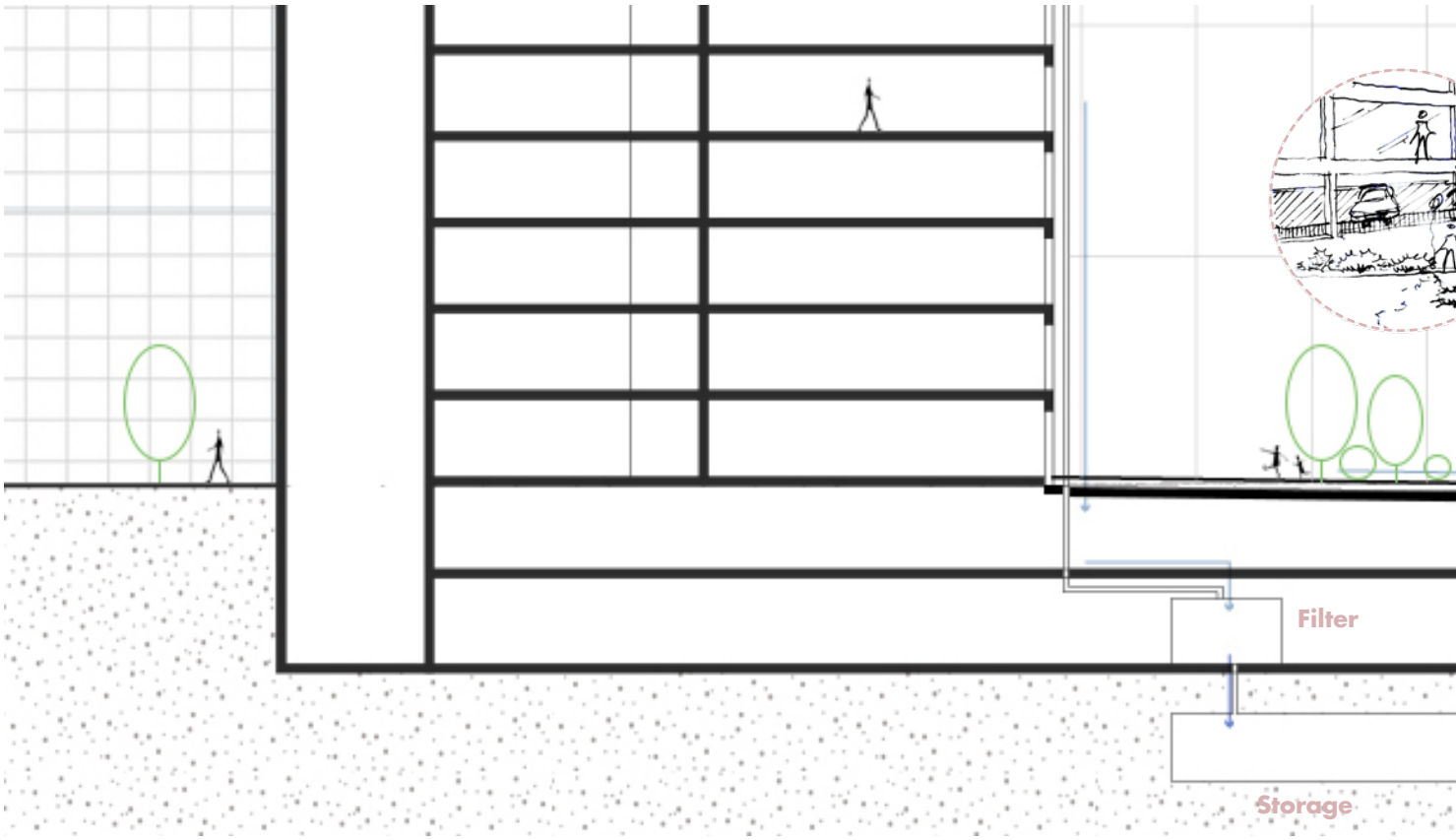
NEW HOUSING & PUBLIC SPACE

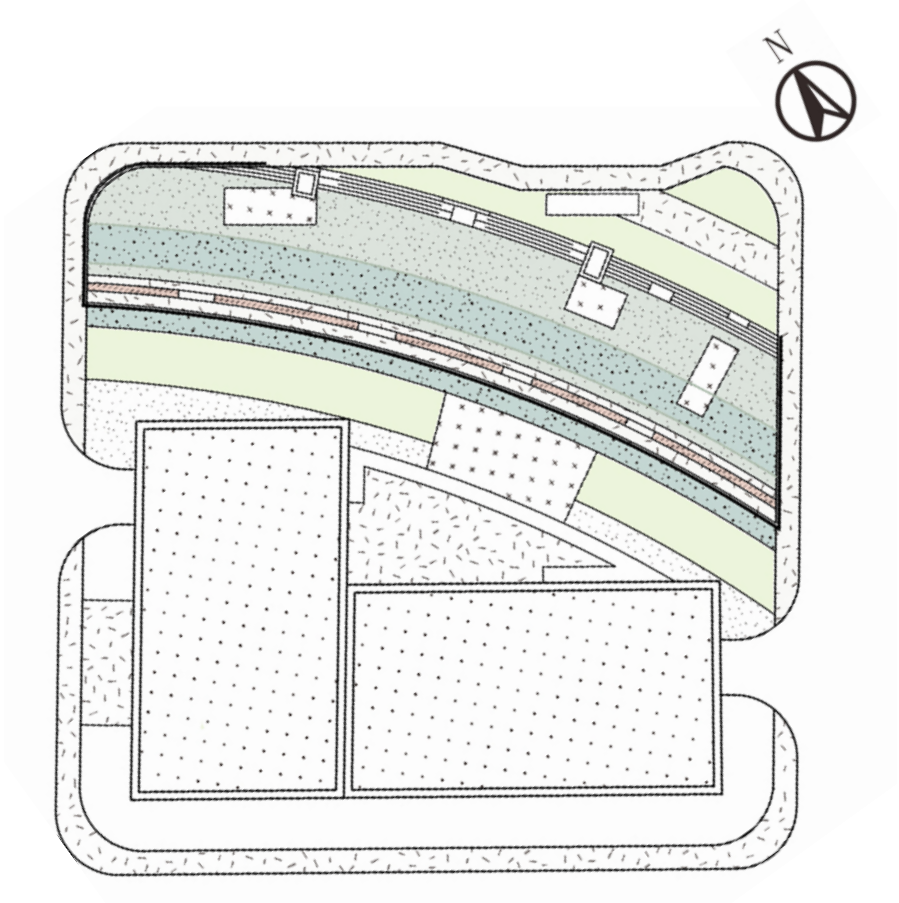
The Rain Ring is set to decrease the water overflow from the south downtown area.
It is an artificial landscape, which digs a ditch to slow down the water flow, to let it infiltrated by open soil and storage for reuse. The ring has three layers: the ditch layer, ground layer and building layer. (Fig. 4.32)

FLOODING

There is multi-level safety approach in the Netherlands: prevention, sustainable spatial planning and disaster management. (Stowa, 2014) Facing different phasing of flooding, it is also important to deal with how to defence flooding; how to decrease flooding; and how to decrease the effect of flooding.
What's more, also resilient to deal with different amount of flooding. The section of the ring is designed to be resilient to flooding, ditch to defence





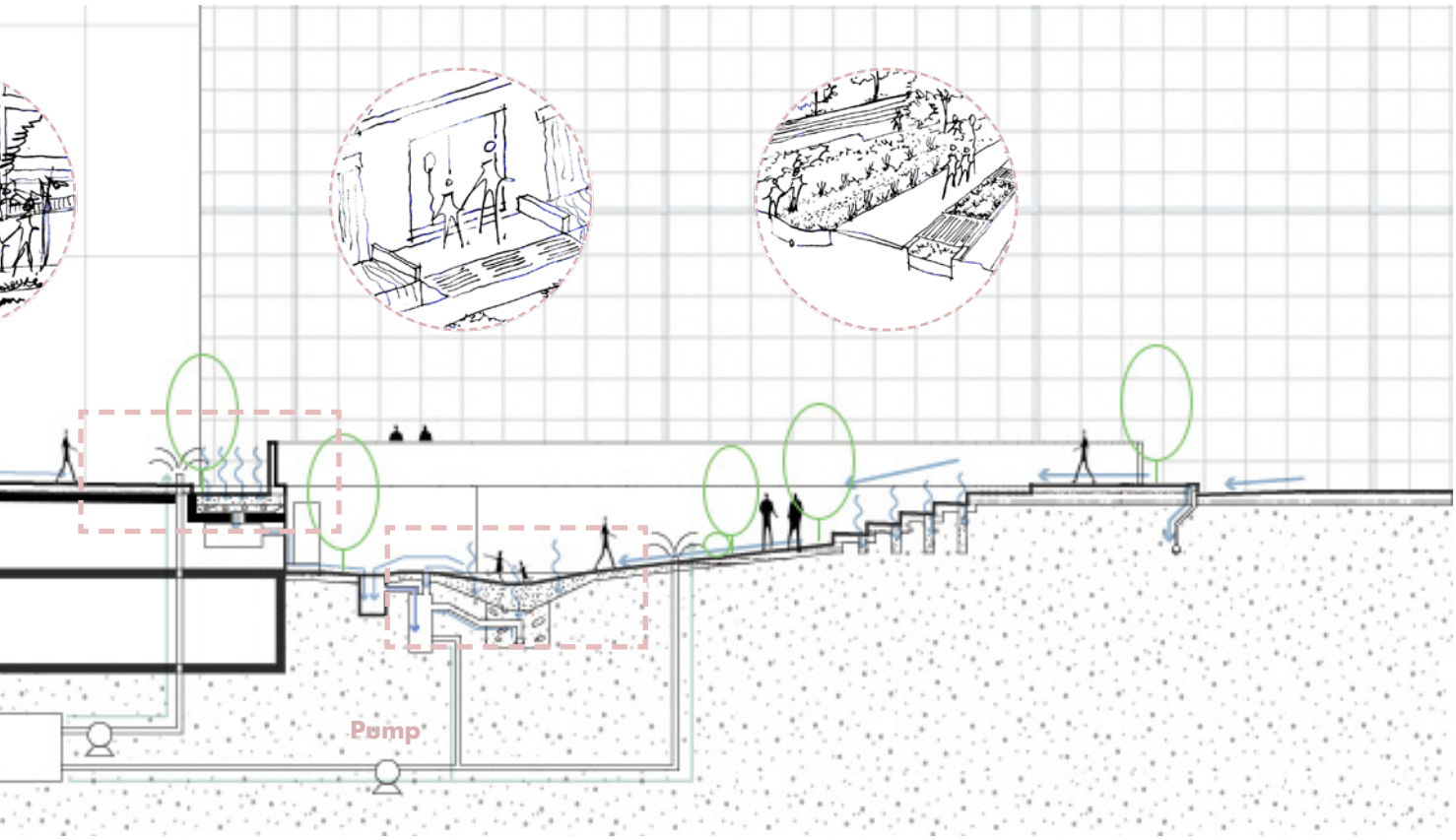


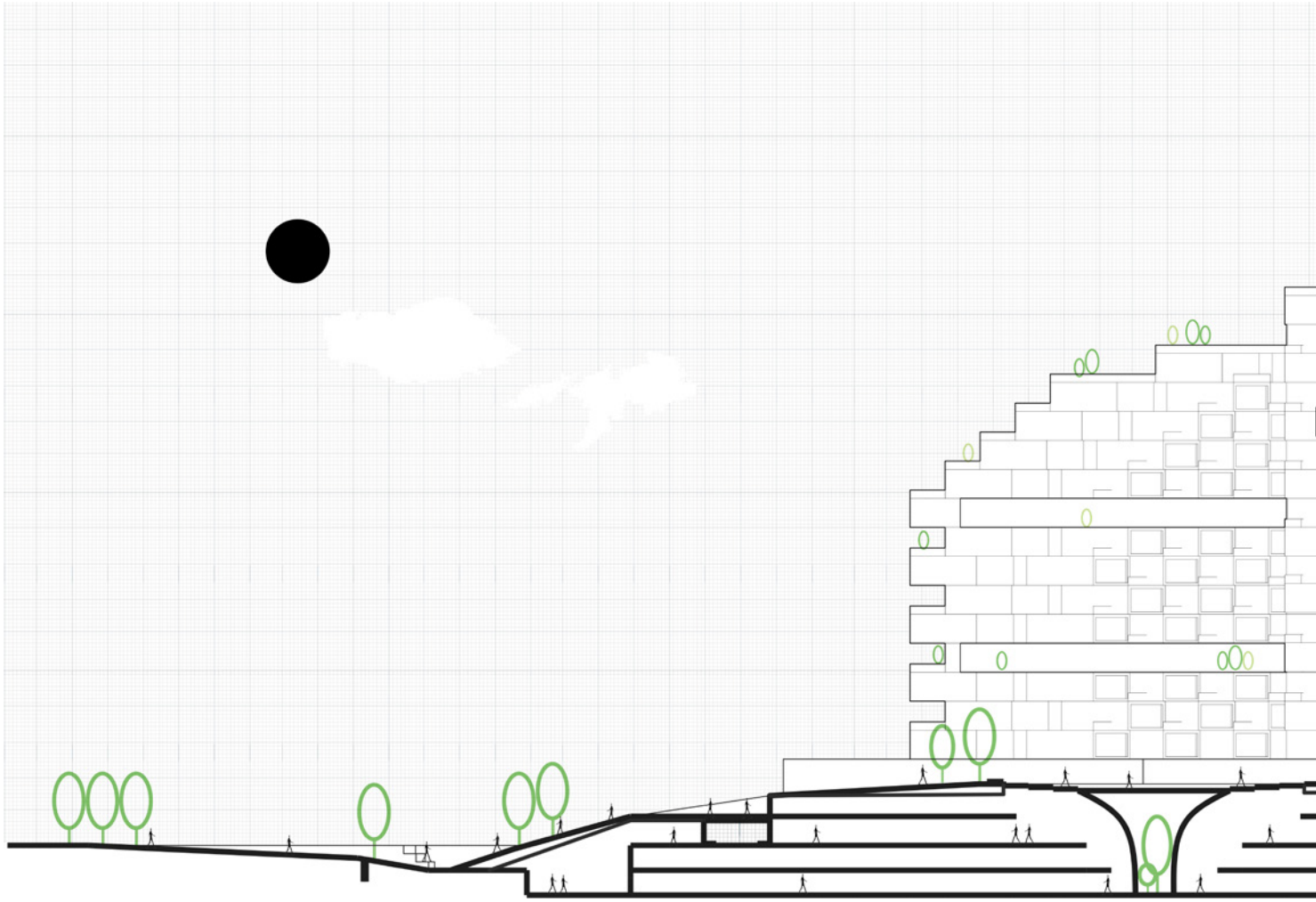
flooding, wadi to decrease flooding, and obstacle to decrease the damage of flooding, as shown in Fig. 4.33.

DETAIL PLAN

Near the side of the new residential area, it is a vertical wall, on the top of it is a water management landscape, which can infiltrate and store water, when it cannot hold the water, the wall turns to be a waterfall.
On the other side, because of the limitation of space, it is first a step (the first step for water infiltration) and then the slope to concentrate, infiltrate and store water. (Fig. 4.34)
In this ring, when there is no rain, people can have public activities like dancing, camping and skating.

Fig. 4.32 | General section of Rain Ring
Fig. 4.33 | Detail section of Rain Ring
Fig. 4.34 | Detail plan of a part of the Rain ring





RAIN ROUTE

GREEN BARRIER

REPLACEMENT OF I-45

After removing the highway I-45, following the strategy, it is built to a green barrier between the downtown area and midtown area to divide different areas and give them identities. In order to make it have more vitality and have a higher usage, it combines the function of green space and commercial- the lower level building is commercial and has a vertical facade facing the downtown direction; the top layer is a roof park, which is a slope towards the midtown direction. (Fig.4.35)
People can have fun both on the top and inside the building. Put the parking space to concentrate on the underground layer.

WATER RESILIENT

To make the green barrier more resilient to flooding, add a rain route on it to flow the water from the south downtown area to Buffalo Bayou. The section of rain route is the same as the ditch layer of rain ring, which infiltration, filter and then flow into the rain pipes, while the scale of water infrastructure is much bigger than the ring, as this is the place where water is concentrated. (Fig.4.36)
On the top roof park, there is a water square, also helps manage the rain water overflow. Under the water park is an indoor green space. When the water square is full, water will overflow down to the indoor green space and water it. The water not be used will flow to the rain pipe after soil infiltration and filter. (Fig.4.37)

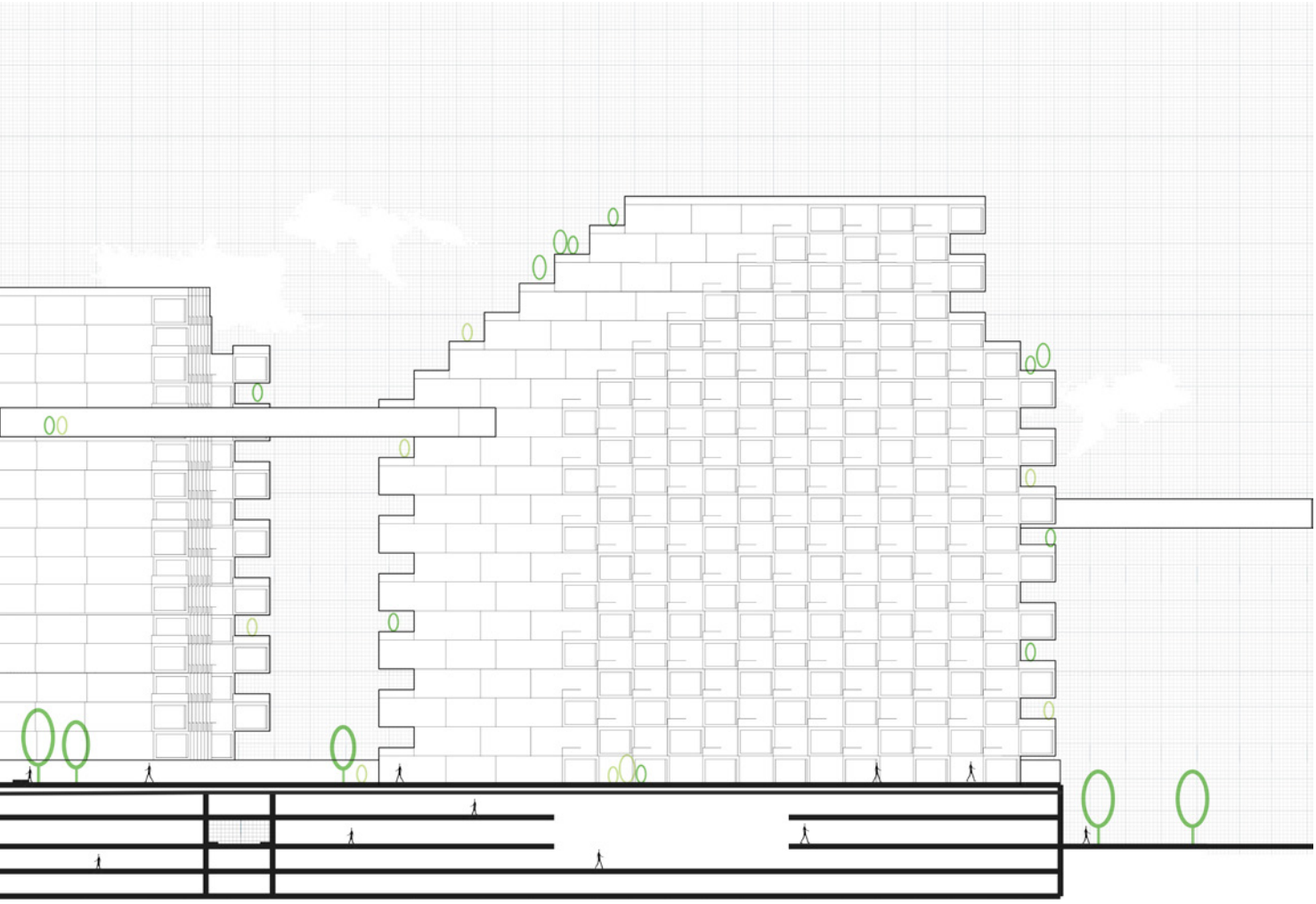
Fig. 4.35 | General section of Green Barrier
Fig. 4.36 | Detail section of Rain Route
Fig. 4.37 | Detail section of Green Barrier

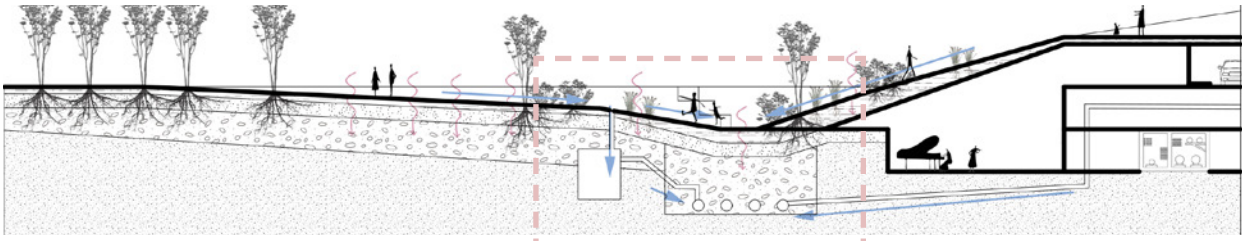
Top layer soil

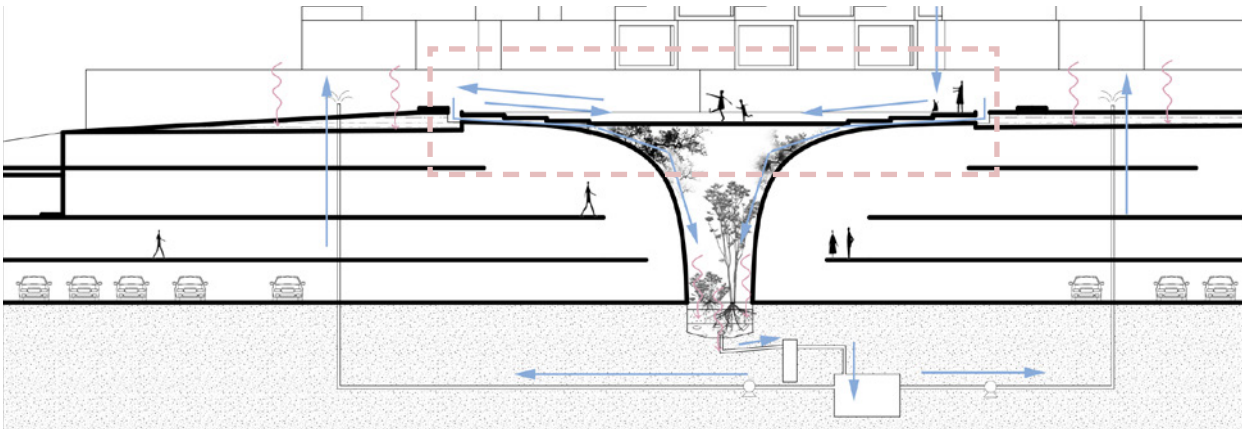
Infiltration layer soil

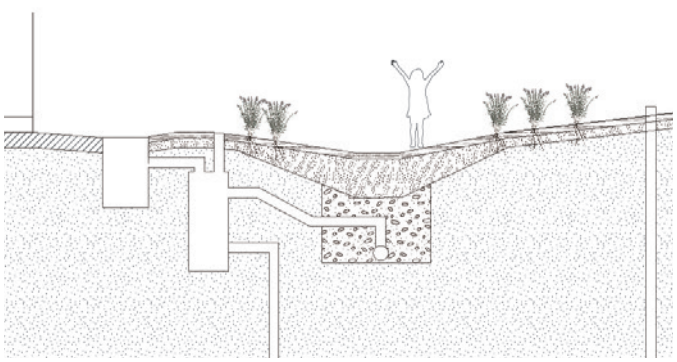
Filter layer soil

Clay









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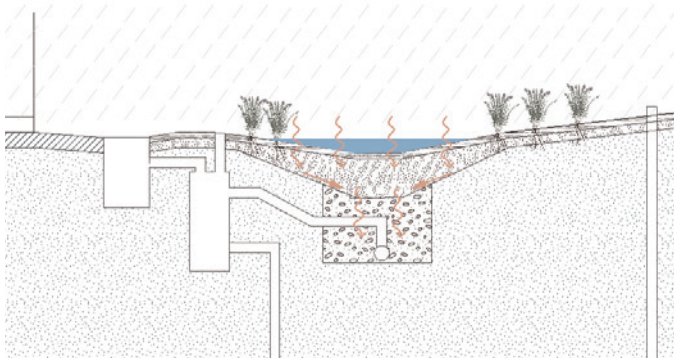

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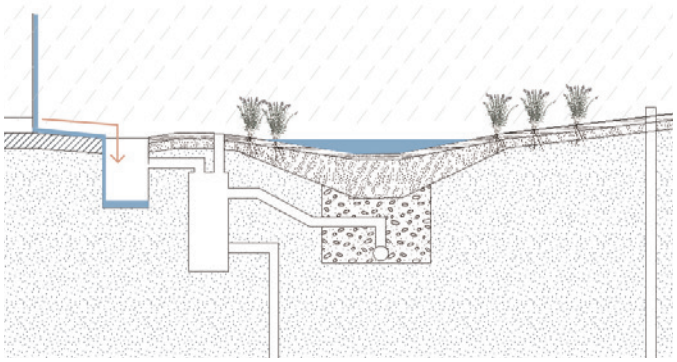

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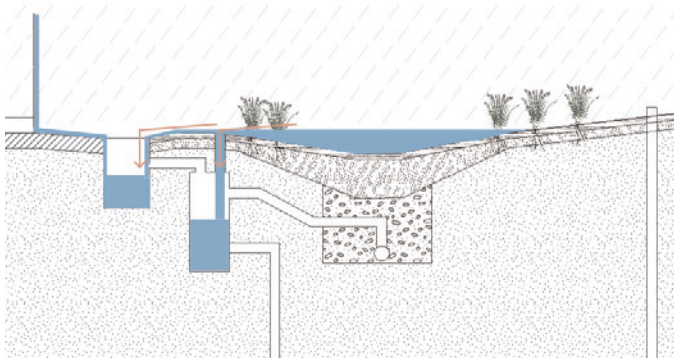

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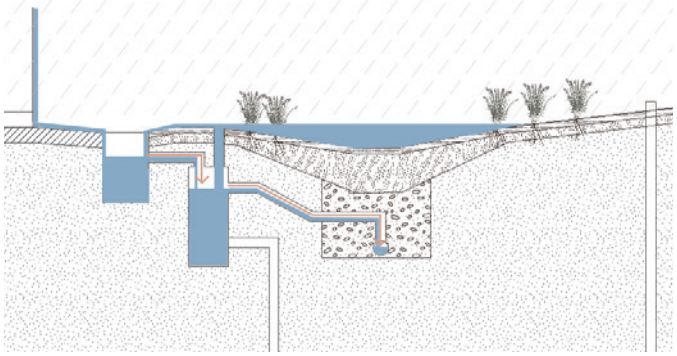

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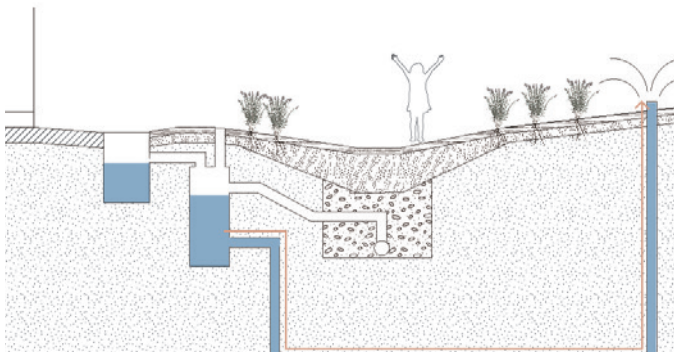


6

There are three layers of soil to manage the rain water, top layer for plants to grow, a mid layer for infiltration and bottom layer for filter and then small amount of rain water will flow to the original clay and most rain water flow to the pipe. During this process, the soil absorbs some amount of water, and the water flow into pipes have already been filtered for the first time.

HOW TO BE RESILIENT?

The reason why Houston is easy to be flooded is the feature of the rain that there is always a huge amount of rain per unit time. Therefore, in order to decrease the flooding, slow down the overflow by a multilayer management can be a feasible method.

What's more, to be resilient to a different amount of flooding, it is also necessary to make multilayer management.
-When there is no rain, the ring act as the public green space; (Fig 4.38-1)
-When there is light rain, there is water in the ditch and slowly infiltrated by the soil; (Fig 4.38-2)
-As it rains harder, the ground level can not hold that much water and start to flow to the canal in ditch layer; (Fig 4.38-3)
-When it rains more, both the canal and the ditch can not hold the water and flow to the underground storage; (Fig 4.38-4)
-The most serious situation is the underground storage is also full, and then water goes to the pipe and flow away; (Fig 4.38-5)
-After the rain, there is water stored in the storage facility, and can be pumped to the ground and ditch level to water the green space. (Fig 4.38-6)

This resilient water management is used in a different urban environment as the pink squares shown in Fig. 4.32, Fig. 4.33, Fig. 4.36, Fig. 4.37.

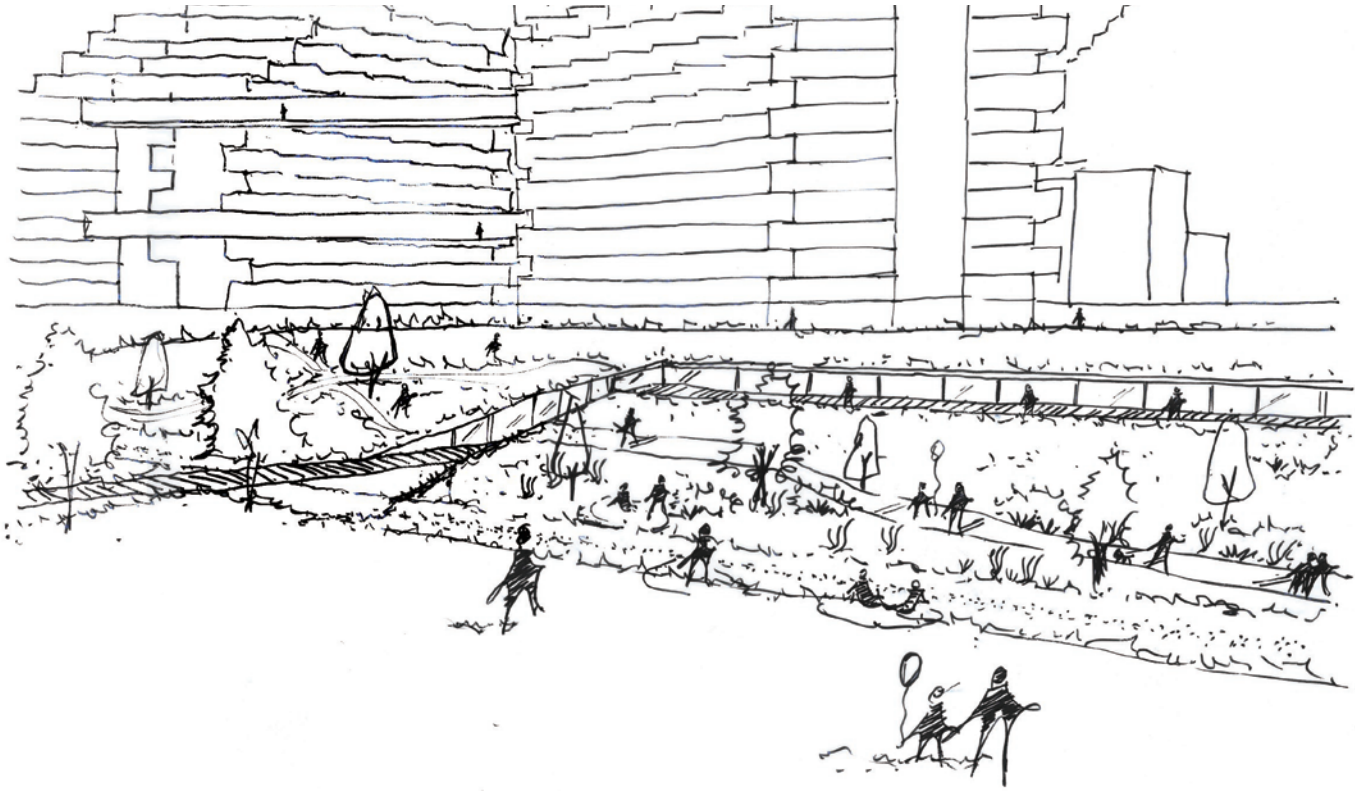


Fig. 4.38 | Scenarios of Rain ring/route
Fig. 4.39 | Eyelevel perspective of Green Barrier

Top layer soil

Infiltration layer soil

Filter layer soil

Clay

RESILIENT V

MULTILAYER

To make the walking system for people more resilient, use the multilayer walking system, for different destination, in different weather and for future increase in space demand.
The walking space is mainly divided into 5 types: underground tunnels; ground outdoor pavement; ground indoor corridor; sky indoor corridor and sky outdoor corridor. (Fig.4.40,41)
For the current situation, there are already some underground tunnels combined with the parking facilities linked to office buildings, but the entrances are all inside the buildings defending flood, therefore, people can hardly find the active underground system. Therefore, adding the sky corridors which can be seen from the street and make different layers connect with each other in vertical, which can motivate the street life and meanwhile prevent the tunnels from being flooded.
There are also corridors indoor and outdoor, because of the climate. The summer is so hot that people cannot walk outdoor for a long time, so they can choose to walk indoor, when the weather is fit enough people can still choose to walk outdoor and enjoy the street life.

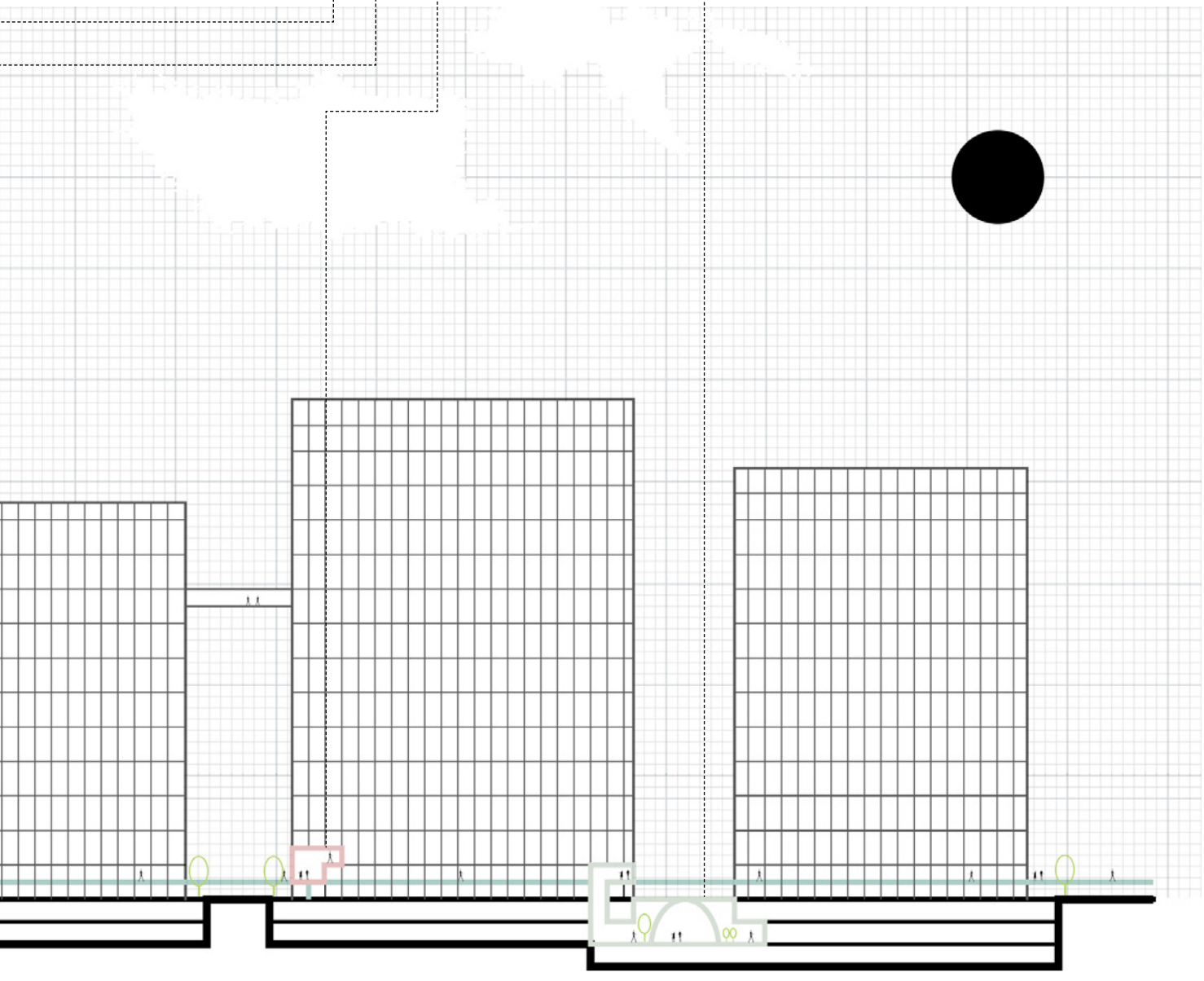
Underground tunnel

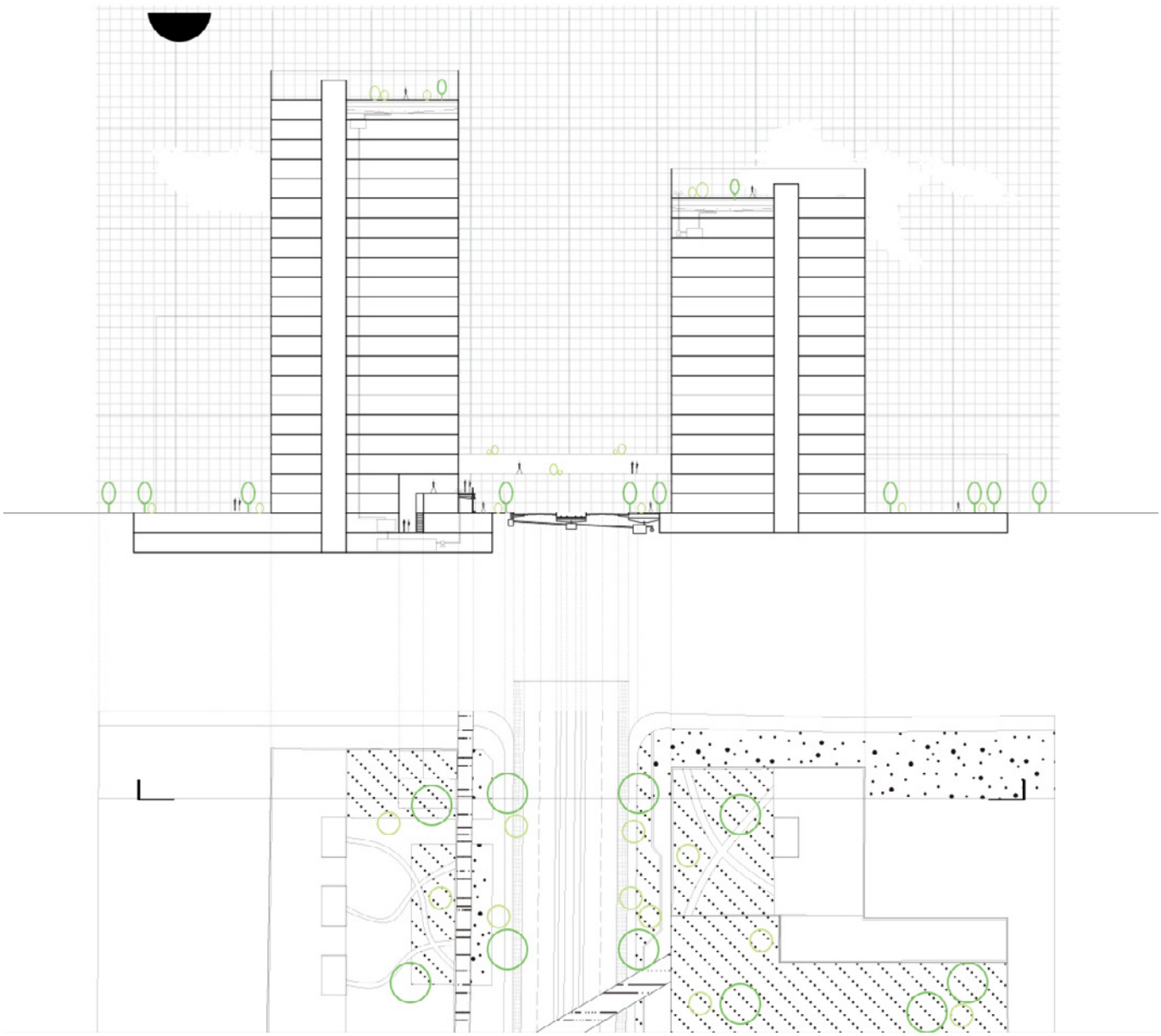
Sky corridor indoor

Connector

Fig. 4.40 | Plan of multilayer

Fig. 4.41 | Section of multilayer Main Street





MAIN STREET

MULTILAYER & WATER RESILIENT DESIGN

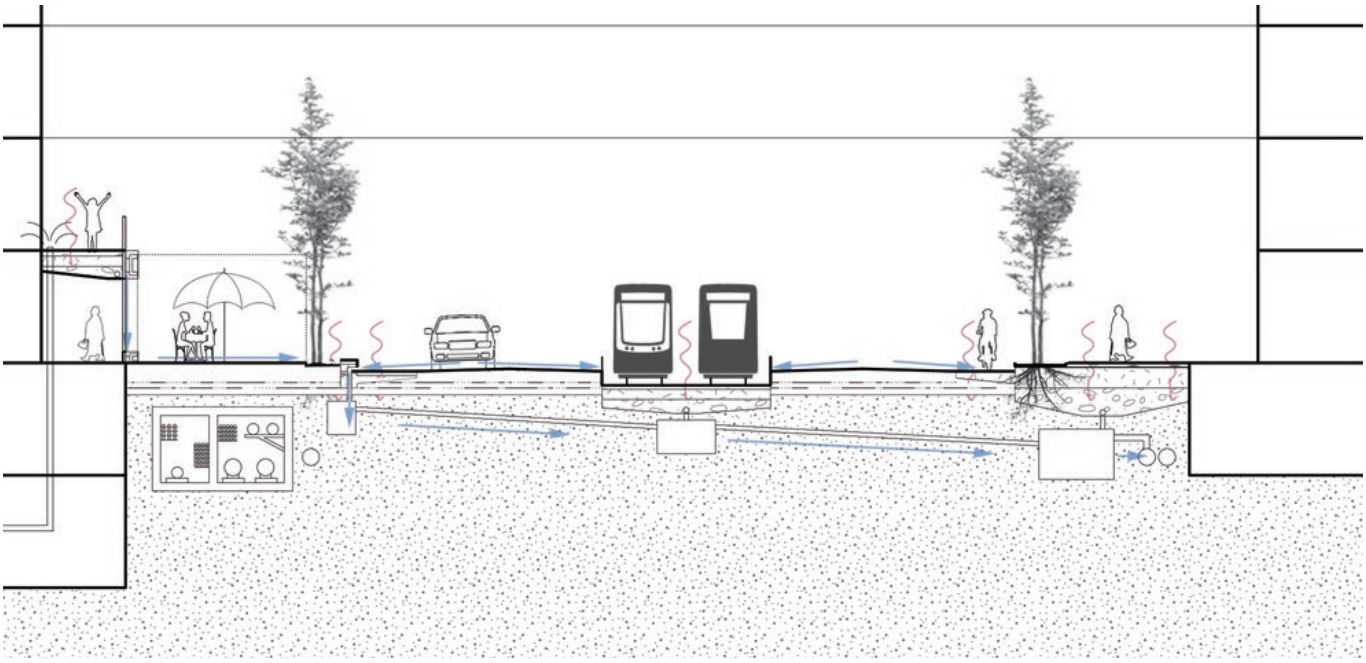
The Main Street is the most complicated part of both vertical multilayer and different traffic systems.
Containing walking space, biking lanes, car lanes and tram lanes in horizontal and all the five types of walking space in vertical. (Fig.4.42,43)
To combine the different layers, there is always an enlarged node at the intersection, to organize the vertical traffic.
By going first upstairs to the second floor and then downstairs to the underground, there is no entrance directly to underground from ground level, therefore, it defence the flood and keep walking space cool.

PHASING

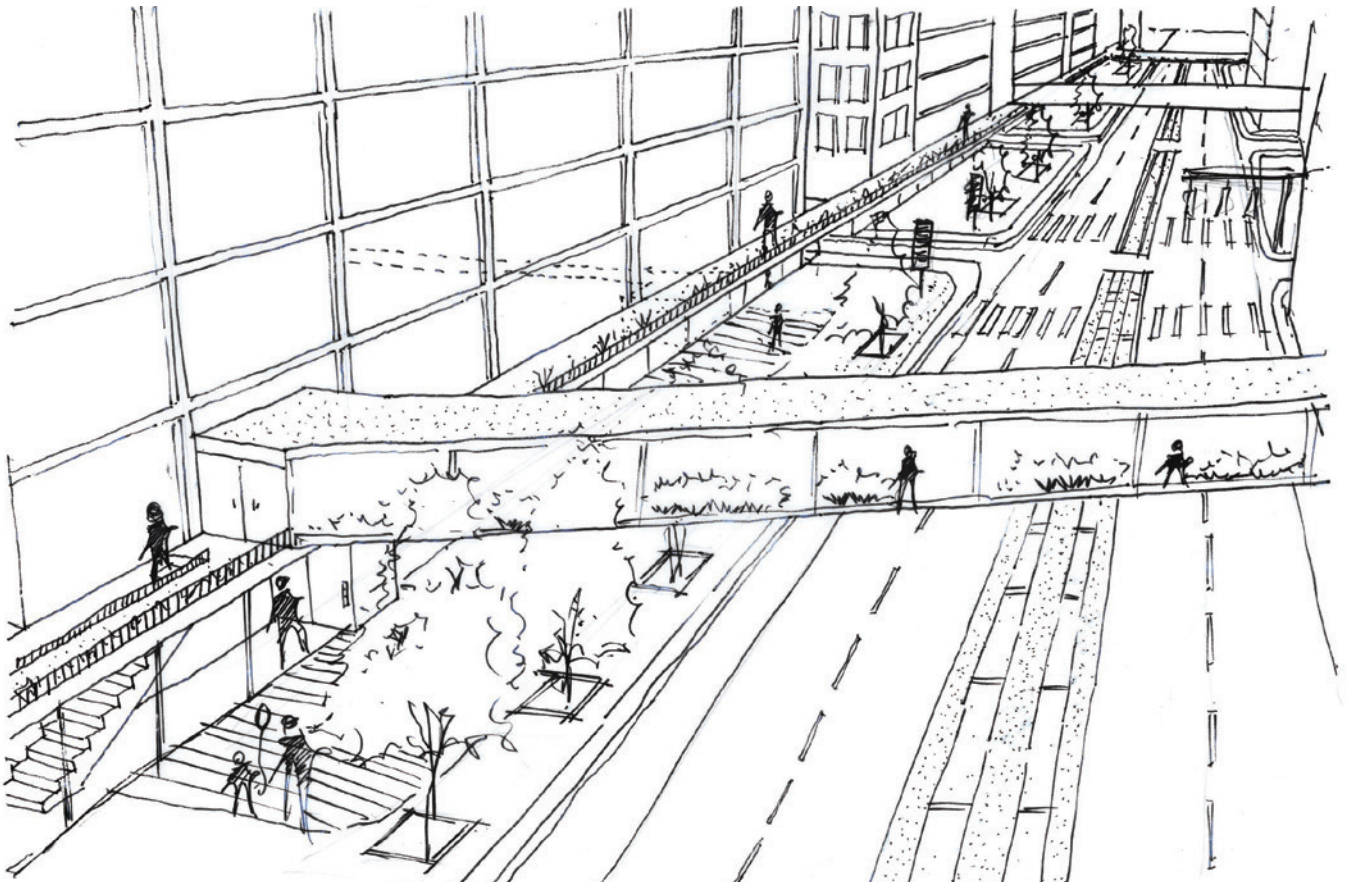
The development of the Main Street is also resilient to different scenarios. For the current situation, people can only see parking garages and empty office hall from the street, while later on, with the construction of the multilayer walking space, people can explore more space on floor and meet more people; In the future scenario, when the office modules are back to the street, people will have a true and rich street life. (Fig.4.44)

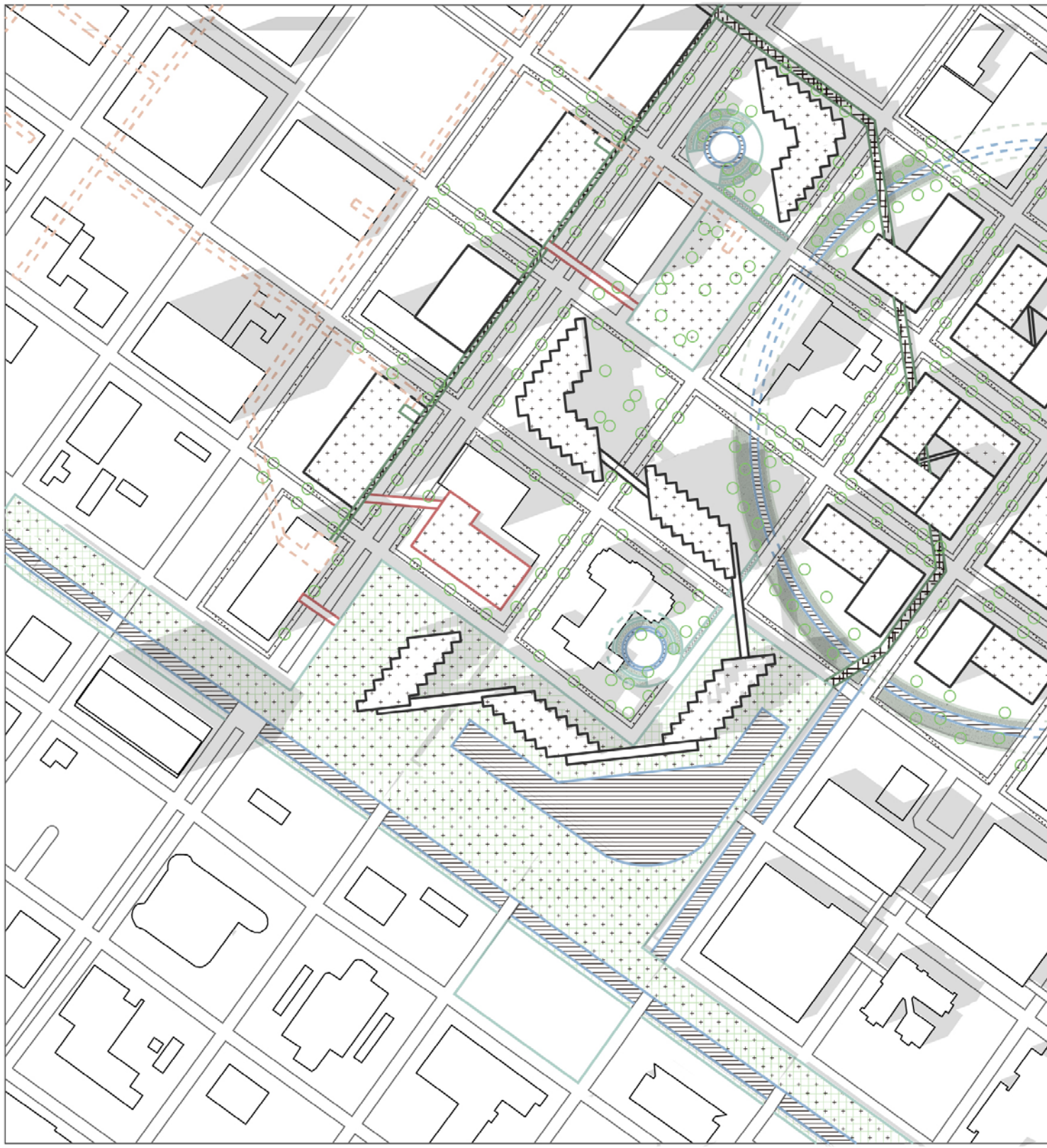
Fig. 4.42 | Plan & section of Main Street
Fig. 4.43 | Detail section of Main Street
Fig. 4.44 | Scenarios of Main Street
Fig. 4.45 | Perspective of Main Street

Open soil
Artificial surface
Public space




HOT! WHERE ARE THE OTHER PEOPLE?
HERE IS THE ENTERANCE OF UNDERGROUND!
WELCOME UNDERGROUND!
NICE BAR!





MASTER PLAN

SOUTH DOWNTOWN

The design mainly consists of 3 parts. The rain ring and rain route correspond to flooding resilient, design infrastructure as a landscape to create more public space while defence the flooding.
There are two newly designed modular neighbourhoods, one is more regular form to explore the basic rules of how can a modular housing concept adapt to the grid of Houston. Based on the first neighbourhood, using the same modulus, the second neighbourhood trying to optimize the living environment of modular housing. Applying the same modules but different stacking methods creates a private courtyard that improves the quality of life in modular homes.
The rain ring is combined with modular housing 1 to make a more close but mixed use pilot neighbourhood and rain route is combined with modular housing 2 to build an ecological environment friendly neighbourhood.
With the Main street, these three systems are linked into a complete network which is designed human oriented and aiming to make a resilient design adaptable for different future scenarios.

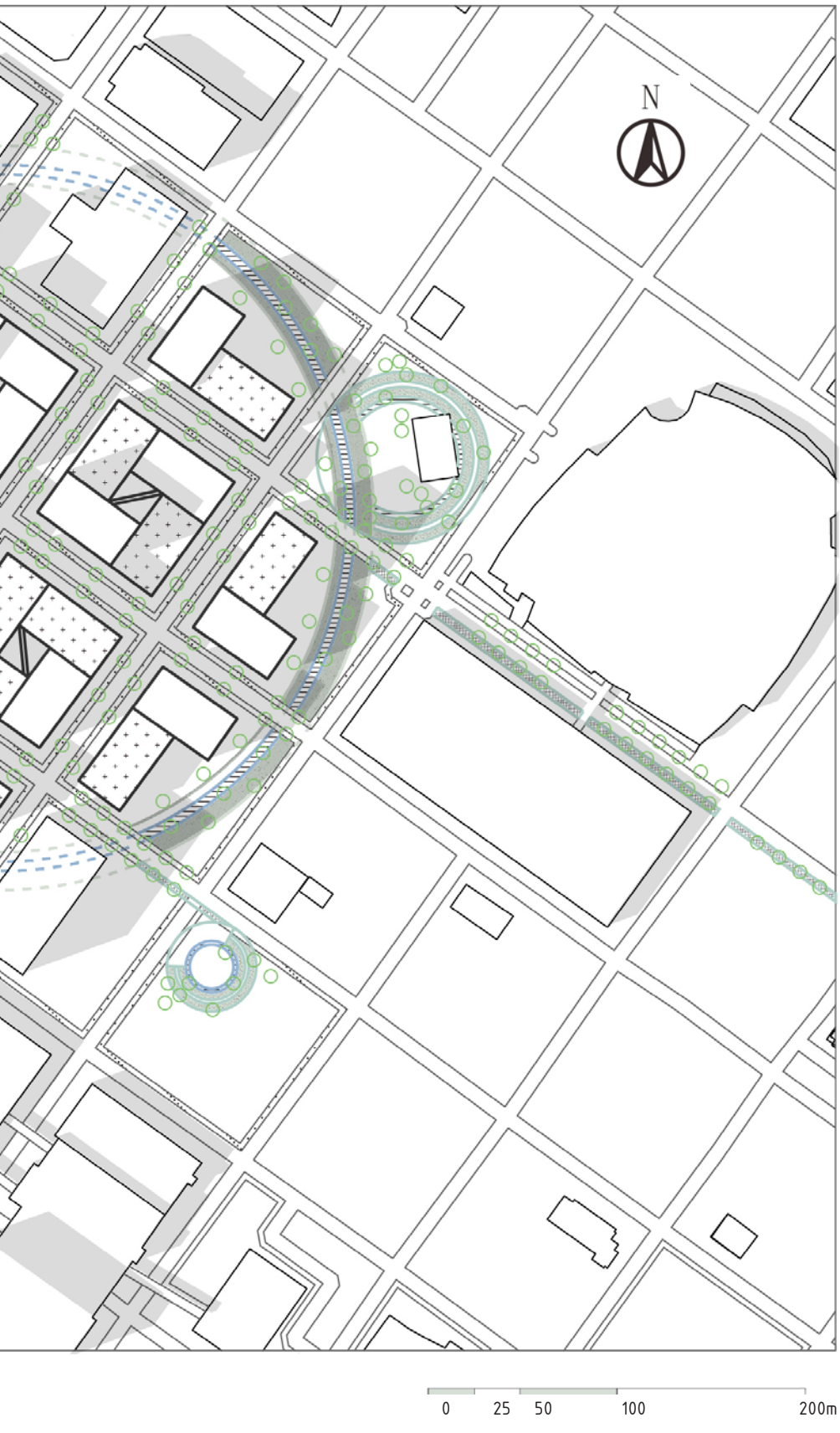
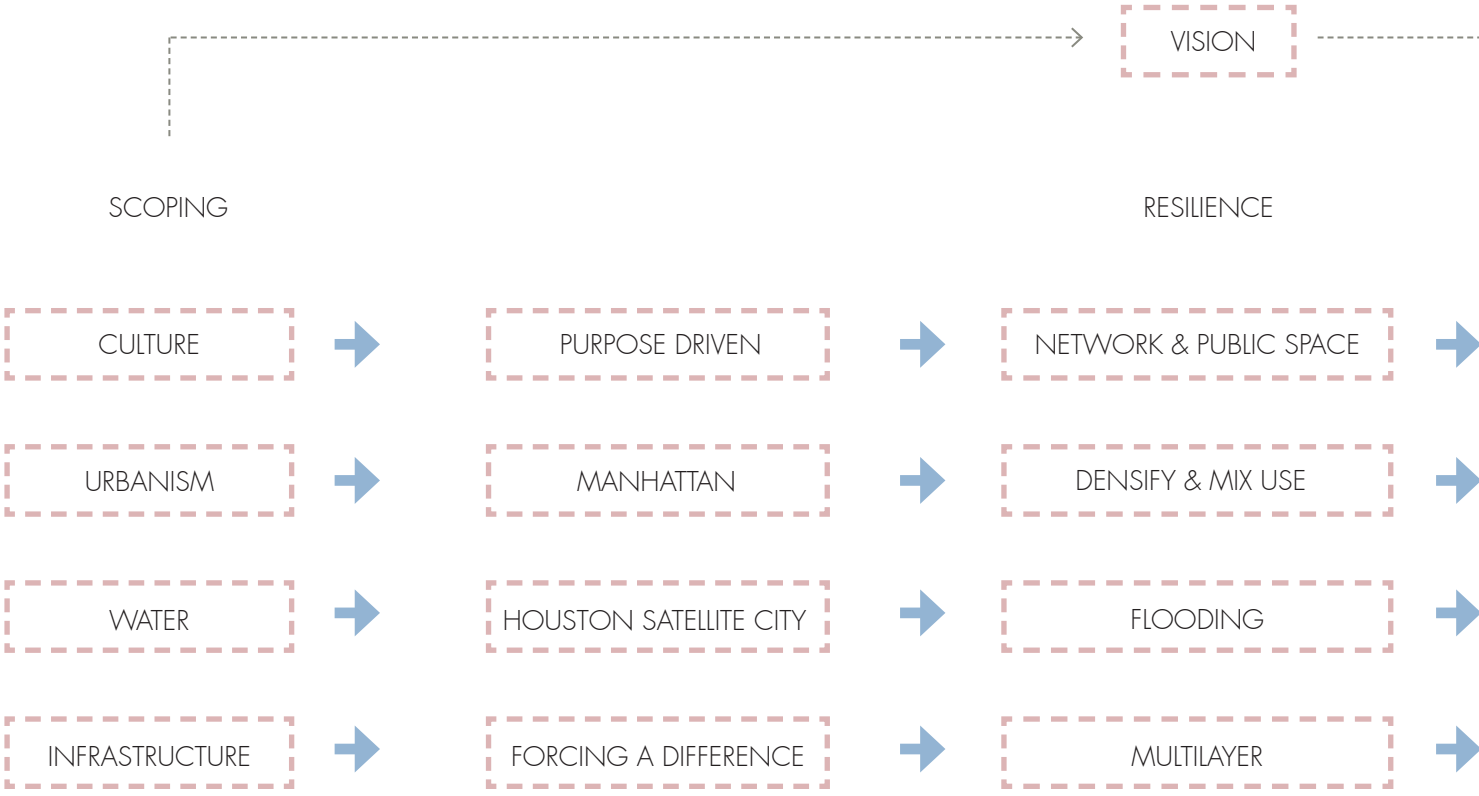


Fig. 4.46 | Master plan of south Downtown Houston

Legend

- New building
- Roof garden on high rise
- Rain route
- Roof garden
- Green corridor
- Rain ring
- Underground rain route
- Corridor
- Undergroung tunnel
- Modular connector
- Pavement



CONCLUSION

HUMAN ORIENTED

Starting from the scoping of urbanism, water, infrastructure and culture, corresponds to the aspects and concepts of resilient. The infrastructure construction and urban development designed for resilience are all human oriented, aiming to build a human friendly downtown area.

SCOPING - RESILIENCE

Use the concept of 'Manhattan' in urbanism, densify the existing empty area of the downtown area and make it mixed use to achieve resilience.
Use the concept of 'remove some impermeable infrastructure and replace with green space' in water aspect, design water management infrastructure to adapt to the alternative amount of rainfall under the climate change scenarios.

Use the concept of 'multilayer' in the infrastructure aspect, design different layers of traffic systems to adapt to different weather, travel purpose and future travel method change.
Use the concept of 'incentives& awareness to culture change' in culture aspect, design network and public space to create more awareness and guide people to change the life style step by step.

RESILIENCE - HUMAN ORIENTED

When densify the downtown area, although the main function is residential, it still mixes other functions like office, commercial, entertainment and green so that people can have different living experience in the tower.
The infrastructure built to manage flooding issues is also designed as a landscape, where people can have public activities on it or underneath it. So the infrastructure has abundant functions that it will not act as a barrier in the city but an urban catalyst to make urban vitality.
The multilayer infrastructure gives people not only more space to walk, but also a better space to walk in the hot or cold weather and clear directionality.
The network and public space are designed to be resilient to scenario alteration. While at the same time, it is the place where people can have public activities in a walking distance and on human scale.

In conclusion, the human oriented resilient design is a pilot experience in Houston, in order to make people aware of living in a more sustainable way to protect themselves from worsening the climate change.

HUMAN
ORIENTED

PUBLIC ACTIVITIES

MIXED USE RESIDENTIAL

INFRASTRUCTURE AS LANDSCAPE

MORE SPACE FOR WALKING

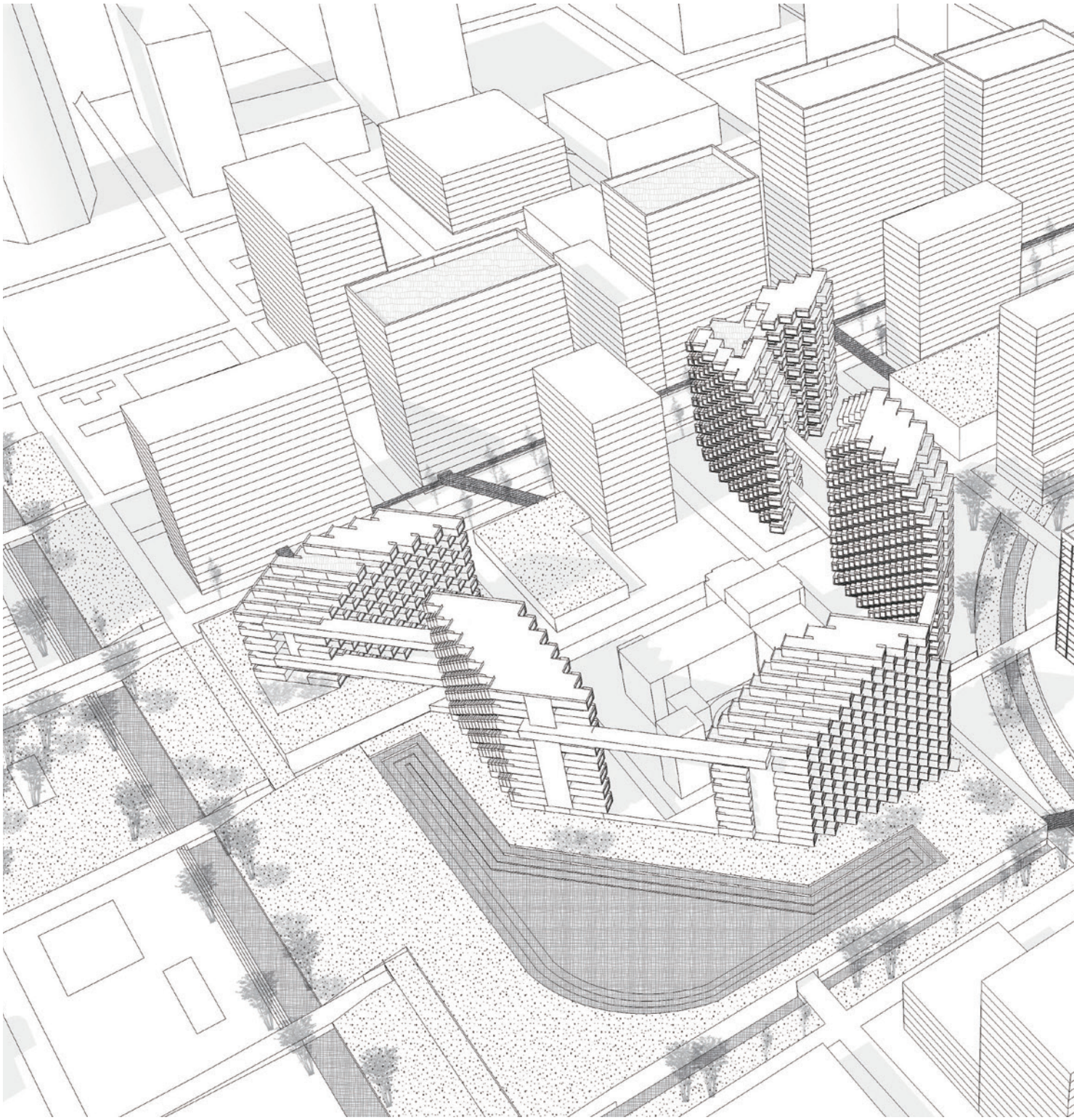


Fig. 4.47 | Bird view perspective

5 APPENDIX

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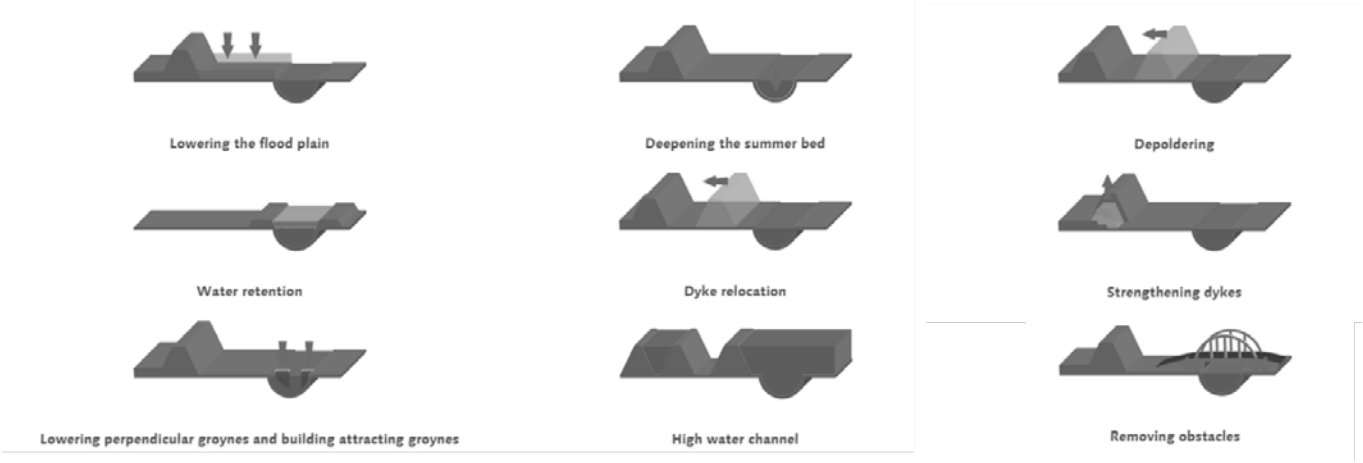

Fig. 5.1 | Room for river, case for Bufalo Bayou area

Fig. 5.2 | Highline, case for I-45 area

Fig. 5.3 | Low line, case for I-45 area

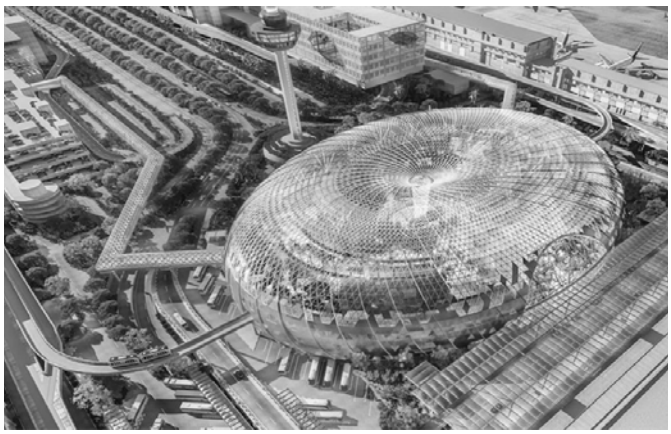

Fig. 5.4 | Singapore airport, case for I-45 area

Fig. 5.5 | Singapore airport, case for I-45 area

Resource: https://www.kickstarter.com/projects/1520010949/new-solar-technology-to-build-an-underground-park
https://skift.com/2019/03/10/singapore-expects-to-open-yet-another-airport-terminal-by-2030/
https://skift.com/2019/03/11/singapores-changi-is-changing-the-idea-of-what-an-airport-can-be/

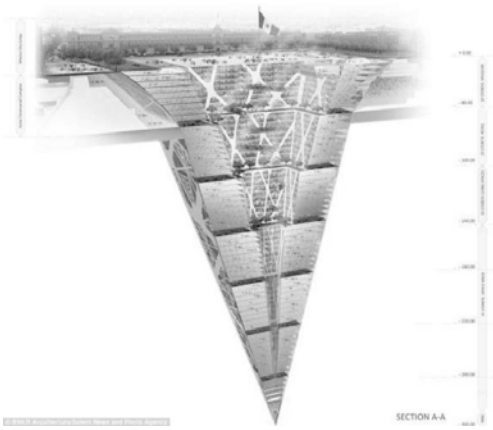

Fig. 5.6 | Groundscraper, case for I-45 area

Fig. 5.7 | walkability project in Paris , case for Convention area

Fig. 5.8 | Real eastate project in Rotterdam, case for Future housing areas

Fig. 5.9 | Real eastate project in Rotterdam, case for Future housing areas

Resource: https://www.funda.nl/nieuwbouw/rotterdam/project-40593750-fenix-lofts-i/