Guidelines on Integrating Nature-based Passive Cooling Options into Urban Planning and Design

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Photo: © Celia He | Dreamstime.com

Introduction

Due to rapid urban expansion, the Urban Heat Island (UHI) Effect is one of the fastest-growing climate challenges threatening Guangzhou's future development. The highest temperature in Guangzhou can reach 39.3°C (China Meteorological Administration, 2020). Rising temperatures lead to an increase in energy consumption and threaten the health sof Guangzhou's citizens. By July 2020, electricity consumption has increased 24% from 2019 levels (National Energy Information Platform, 2020). For every degree of temperature increase, electricity consumption in Guangzhou will increase by 2.7% with residential energy consumption constituting one-third of the increase (Zheng et al., 2020). Moreover, according to Guangdong Provincial Center for Disease Control and Prevention(2013), heat waves could increase mortality by 4.8%.

It is urgent to address the increasing temperature and extreme events caused by the UHI Effects in Guangzhou. There is a dire need for immediate solutions to the various risks presented by UHI and climate change. Many cities around the world have already established an integrated urban cooling system through multi-sector collaboration, including Singapore, New York, Sydney, and others. Inspired by their experiences, the World Bank in collaboration with Guangzhou Urban Planning & Design Survey Research Institute, developed the *Guidelines on Integrating Nature-based Cooling Solutions into Urban Planning and Design*. The Guidelines provide a comprehensive toolkit including 39 cooling strategies to mitigate UHI across scales. Through this report, we address solutions and actions from five dimensions to alleviate UHI effects in Guangzhou: protecting large ecological assets, improving ventilation, promoting permeable surfaces, highlighting the function of city morphology and urban design, and applying green infrastructure.

Urban Cooling Strategies in Guangzhou

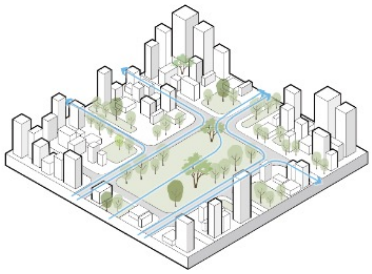
Excessive heat, high precipitation, and strong sunlight are three factors present in Guangzhou's climate. Hence, natural ventilation, passive evaporation, and shading constitute the three major aspects for the city's cooling strategies. *The Guidelines* has been divided into 5 dimensions with 15 tools and 40 actions. Their priority is rated from one-star to three-stars according to a comprehensive evaluation based on Guangzhou's local features.

- ***Smart planning:*** *nature-based solutions, natural ventilation.* Use open spaces, roads, low-rise and low-density areas to form a ventilation system from the mountains to the sea, allowing fresh, cool air to flow into the inner city.
- ***Smart surface:*** *green, permeable and breathing.* Improve the 3D cooling capacity of roads, buildings, public facilities etc. through increasing the use of greenery and reflective, permeable materials for urban surfaces.
- ***Smart design:*** *maximize ventilation and shading.* Encourage urban texture and architectural design that follows the patterns of wind and light.
- ***Smart facility:*** *improve outdoor thermal comfort.* Provide shading and misting facilities in hot spots to improve outdoor thermal comfort.
- ***Smart energy:*** *green transportation, efficient cooling.* Reduce energy consumption and anthropogenic heat emissions with a special focus on transportation and cooling systems.

Smart planning: nature-based solution, natural ventilation

Protect large cooling sources

Protect rivers

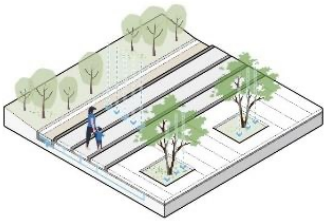


Control ventilation corridors

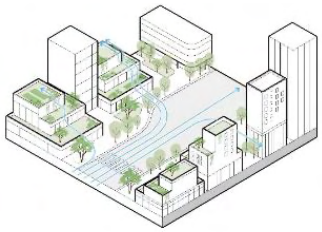
Smart surfaces: green, permeable, and breathing

Parks

Water bodies



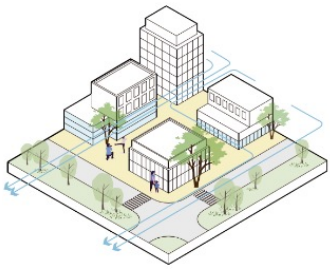
Permeable surfaces



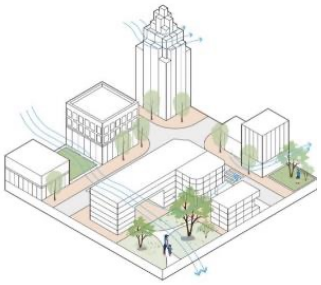
Vertical greening

Highly reflective surfaces

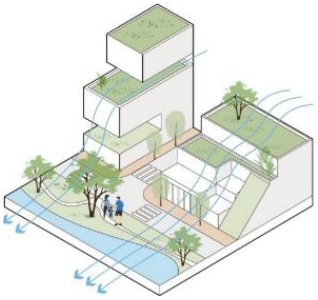
Smart facility: improve outdoor thermal comfort



Road networks and streets



Architectural layout



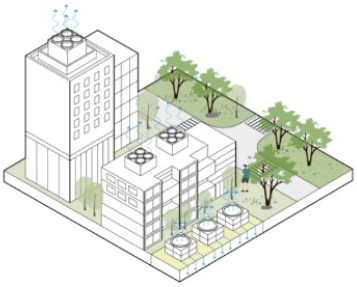
Architectural design

Smart design: maximize ventilation and shading

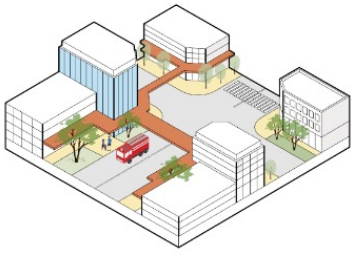
Shading

Spraying

Smart energy: green transportation, efficient cooling



Energy-efficient air conditioning



Green transportation

Source: Guangzhou Urban Planning & Design Survey Research Institute

Smart planning: nature-based solutions and urban ventilation

Protect ecological cooling sources

Priority: ★★

Ecological urban cooling sources include forests, wetlands, rivers, natural parks, and natural reservoirs. They are usually located on the edges of cities or suburbs. Cooling sources have significant impacts on a local climate. They are considered "cool islands" that can relieve the UHI Effect of developed areas.

Strategy 1

Control land development intensity and strictly preserve ecological spaces and natural resources

Ecological cooling sources not only create a comfortable localized climate, but they also offer cool, fresh air which can influence the climate of surrounding areas. Guangzhou is located in a subtropical region, and its climate is characterized by high temperature and humidity. Vegetation grows vigorously with relatively low irrigation and maintenance costs. However, due to increasing urbanization, the surrounding ecological areas are rapidly depleting. Therefore, it is necessary to provide strict conservation.

Actions

- Strictly control the ecological protective boundaries, establish a natural reserve system, limit urban spaces to within 33.3%, from the city scale.
- Protect hills, waterways, ponds and other original natural elements of the site during particular developing projects.

Box 1. Haizhu National Wetland Park.

Haizhu National Wetland Park is located in the central urban area of Guangzhou. After weighing commercial development value with ecological restoration, the 1100 hectares wetland was protected permanently. The wetland implemented a nature-based solution to repair water cycles and improve biodiversity. At present, it creates habitat for 180 bird species, 60 fish species, and 539 insect species.The Haizhu National Wetland Park has been highly spoken of by international organizations such as the UN Habitat and Ramsar Convention.

Haizhu National Wetland Park

Strategy 2

Implement ecological restoration and improve the cooling benefit of ecological cooling sources

There are many benefits that result from ecological restoration. Many restoration efforts have been implemented throughout the past three years. However, there are still many damaged and polluted natural spaces, especially within the urban-countryside interface, that need to be revitalized. Healthy, robust ecosystems can also increase the city's disaster resilience, maintain the city's ecological balance, and provide recreational spaces for residents.

Actions

- Implement ecological restoration on mountains, waterways, forests, fields, lakes, and coastlines.
- Make full use of urban low-lying ponds and abandoned mine pits to carry out ecological construction and build artificial wetlands.
- Carry out effective management against illegal land use, and bring nature back to the people.

Strategy 3

Control the surrounding areas of cooling sources

Fresh air coming down from hillsides is important for urban areas. However, this downhill air flow can be easily blocked or interrupted by adjacent buildings or dense developed areas due to gravity. In this context, maintaining vegetation intensity on sloped hillsides is essential to promoting air flow. In order to bring the cooling benefits further into the urban area, it is imperative to control the development of surrounding areas.

Actions

- Strictly control the set-back distance of buildings. Apply low-density construction when possible.
- Provide corridors perpendicular to waterfronts or downhill to facilitate air flow.
- Control the height of buildings. The buildings should rise in levels as they move further away from cooling sources.

Box 2. Huadu Lake, *Stone Pit Transformation.*

Huadu Lake was once the site of three quarries located at the foot of the mountain, which negatively influenced the living environment of surrounding neighborhoods. After implementing an ecological restoration, the stone pits were transformed into Huadu Lake Wetland Park. It has now become a vibrant habitat for wildlife and a recreational destination for residents.

Huadu Lake Wetland Park

Smart planning: nature-based solutions, natural ventilation

Protect rivers

Priority: ★★

Rivers are important routes for the hydrological cycle on earth. They serve as cooling sources winding through the city, and they are substantial components of air flow and ventilation corridors.

Strategy 1

Protect and restore rivers and build a green path network

Guangzhou is located in the Pearl River Delta where the dense network of rivers and canals offers a natural space for cooling. Guangzhou built its artificial water system—the Six-Vein Canal—in ancient times. The artificial waterways were predominantly extended in a north-south direction following the prevailing wind direction. Central areas with limited land resources effectively make use of existing river networks to produce breezes. This poses a less challenging and more feasible cooling method than artificial waterways.

Actions

- Protect main rivers such as the Pearl and Liuxi Rivers, and construct green path spaces.
- Revive water veins, restore historical water systems such as the Six-Vein Canal, and gradually regulate and control the developed environment surrounding historical water systems.

Guangzhou, China. Photo: Zhonghui Bao

Strategy 2

Enhance the control over riverside spaces and expand cooling river spaces

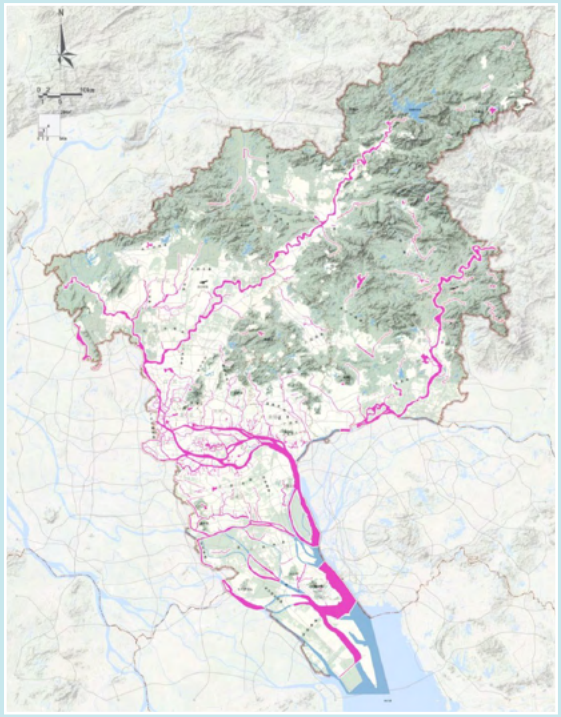
Rivers in the city create local breezes, improving thermal comfort and dissipating urban heat. Due to Guangzhou's high humidity, there should be an emphasis on the combination of blue and green spaces in riversides when optimizing for cooling effects. Integrating active transpiration, shading, local breeze circulation, and other climate regulation effects is recommended to maximally offset the impact of river humidity. In addition to cooling the city, beautiful landscapes along the rivers could offer more recreational spaces to residents, while enhancing the city's rainwater storage capacity.

Actions

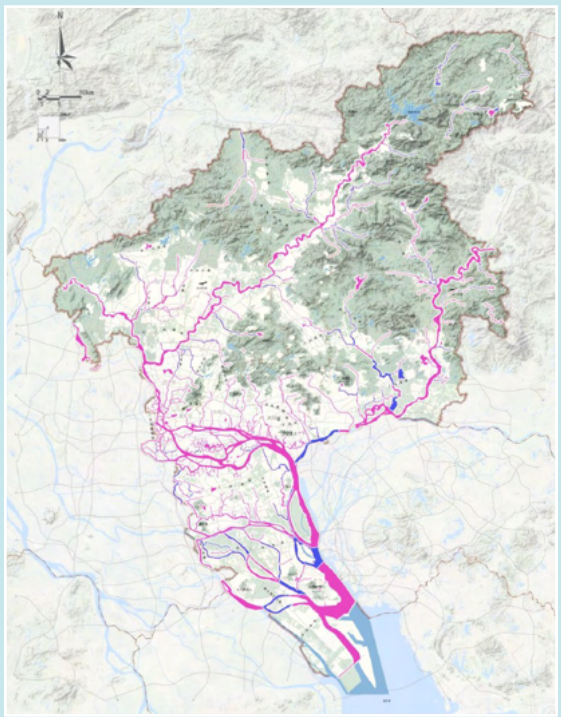
- Enlarge the interface of river banks and create a continuous and open cooling space along the riverside.
- Control the river corridors and connect mountains in the north with oceans in the south.
- Constrain the "wall-like" development along the waterfront and increase linear green areas.

Box 3. Guanzhou's ecological river belt

Guangzhou officially issued the Guangzhou ecological river belt master plan. This proposal states that, by 2025, the city will build 1,506 kilometers of ecological river belt, and the city will build 2,000 kilometers of ecological river belt by the year 2035. At the same time, the master plan identified the main tasks of water resource protection, water safety warnings, and water environment improvement. It also set out detailed construction plans and protection measures in the construction of ecological river belt.



2025: total length **1506** km



2035: total length **2000** km

Source: Guangzhou Urban Planning & Design Survey Research Institute

Source: Guangzhou Urban Planning & Design Survey Research Institute

Enning Canal is one of Guangzhou's historical channels. The revitalization of Enning Canal was a successful project that integrated water elements with urban design. Nowadays it not only creates vibrant waterfront scenery but also provides an active recreational areas for visitors.

Smart planning: nature-based solutions, natural ventilation

Control ventilation corridors

Priority: ★★★

Allowing natural wind flows to move through hot urban areas is an important cooling strategy. The ventilation corridor system is a prevention and control measure that, while not increasing costs, will generate huge benefits such as accelerating air flow, reducing humidity, preventing air pollutants aggregation, and protecting the public health.

Strategy 1

Establish ventilation corridor systems covering multi-scales

Guangzhou enjoys abundant background winds, including sea winds, river winds, downhill winds, and monsoons. Any barrier to, or stagnation of, natural air flow may hamper outdoor thermal comfort and exacerbate the UHI effect. The citywide wind ventilation is dominated by macro factors such as topography and rural surroundings, while the local circulation is more influenced by the smaller built environment. Therefore, it is necessary to build ventilation system in different spatial scales from macro to micro.

Actions

- Identify ventilation corridors in the territorial space master plan at a citywide scale.
- Delineate a specific scope of ventilation corridors and implement ventilation corridor control requirements in a detailed plan.
- For urban design of strategy areas, perform specific wind ventilation assessments and design for both major breezeways (linear roads and open spaces) and minor breezeways (between and within buildings and blocks).

Strategy 2

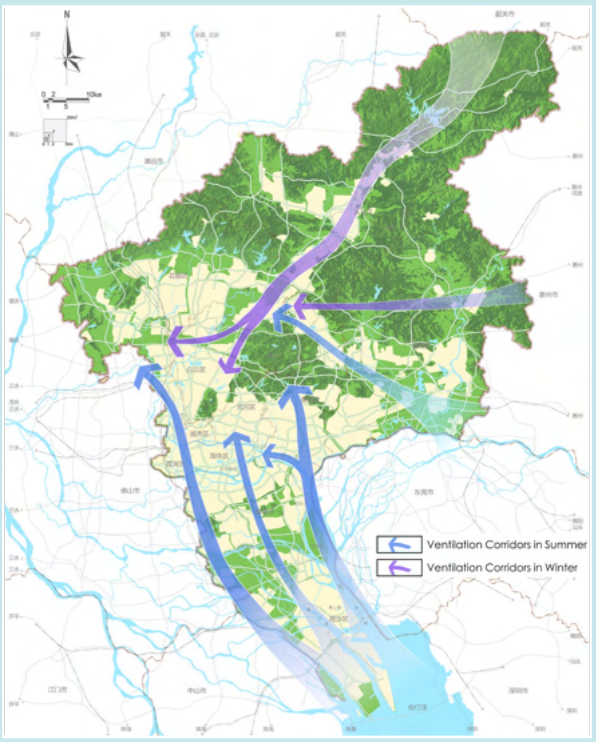
Enhance developing control on the ventilation corridors to improve permeability

The construction of ventilation corridors does not mean large-scale demolition and construction. Instead, ventilation corridors should make full use of existing urban green areas, roads, rivers, and other public spaces to create continuous wind pathways and control new obstructions like high-rise buildings. Building clusters located inside the corridors which block the wind should be phased out during the urban renewal process.

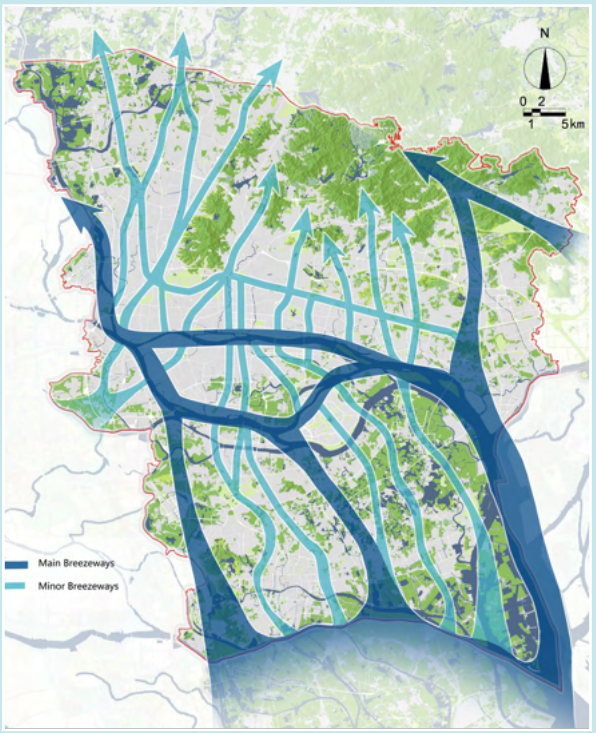
Actions

- Strictly protect open spaces located in the ventilation corridors such as water systems and green areas.
- Limit new comprehensive development in sensitive areas such as air intakes and windward zones.
- Establish a negative list for project entries and forbid the entry of any air-polluting projects.
- Set up an indicator control system for allowed small-scale and essential developments that includes building density, building length, building height, and building separation.
- Provide guides for building orientation and disposition in ventilation corridors, especially neighborhoods bordering water bodies, hills, and streets.

Box 4. Guangzhou's ventilation corridor system



Wind corridors citywide: Based on wind pattern studies, green belts, water bodies, low-rise low-density areas and artificial paths including highways and major roads were linked to form 6 main corridors citywide for wind to blow through the city.



Source: Guangzhou Urban Planning & Design Survey Research Institute

Wind corridors in central area: Based on the study of urban fabrics and ground roughness, a ventilation system of 5 major airways and 22 sub-airways in the central area was planed. The system has south-north corridors as the core and east-west corridors as its support.

Smart surface: green, permeable and breathing

Parks

Priority: ★★

Parks and green areas in cities can bring in the shading and cooling effects of green foliage, enhance the evapotranspiration of plants, reduce the heat island effect, decrease ambient temperatures, improve air quality, and effectively regulate the microclimate. In addition to these ecological benefits, parks and green areas are usually located near residential areas and waterfront areas, which can provide leisure and recreational spaces for residents.

Strategy 1

Increase the number of parks and vegetative cover

Improve the integration of vegetation, shading, and ventilation. Urban parks are able to offer urban cooling benefits not only within parks, but also in the surrounding areas. In compact cities like Guangzhou, parks of varying scales should be infilled among the urban blocks. Fully utilize the blank spaces to increase the green coverage in both horizontal and vertical perspectives.

Actions

- Encourage the construction of parks to build a green network.
- Adopt a model with large parks as the core and small- to medium-sized parks designed in grids.
- Parks within the community must be adjacent to secondary roads. Community-level green squares should not be located next to urban expressways and main roads. They should be located near schools, commercial facilities, or other community public service infrastructure. Greenery should be located in all available empty spaces.

Photo: Wictor Vorobev

Strategy 2

Appropriately configure the vegetation and plant species of softscape areas

The greenery species are the foundation of cooling capacity generated by parks. Trees, especially large trees, have high cooling benefits with more shade and transpiration. Local species have high potential growth rate and low irrigation needs. Species with multi-layered structure can fully use land, sunlight, space, and nutrients to achieve maximum growth.

Actions

- Select tree species with large canopy and leaf coverage, which will effectively reduce direct sunlight. More than 3 trees for every 100m^2 landscaped area are recommended.
- Use a multi-layered structure of trees, bushes, and grasses, with trees constituting no less than 50%.
- The species proportion and planting area of native plants should be no less than 70%.

Strategy 3

Modify the design of the hardscape areas and facilities

Along with the landscaped area, parks also consist of hardscape areas and facilities. Climate-responsive design of these parts can better integrate with the vegetation and greenery and provide space for recreational and sports activities of residents.

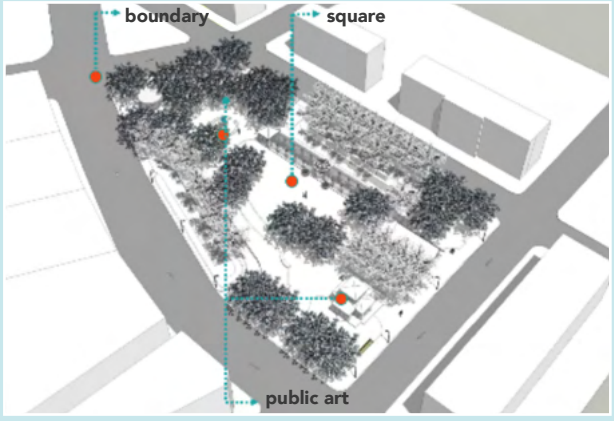
Actions

- Incorporate water features such as fountains and waterfalls, sheltered public arts such as pavilions, corridors, and fixed sheds to multiply cooling effects.
- The square at the park should be paved under tree canopy with a shading area of no less than 45%.
- Do micro-topography treatment to generate temperature differences between sun-facing and back-sun surfaces, thus improving airflow.

Box 5. Construction of pocket parks in Guangzhou

Guangzhou has transformed inefficient and unused plots of land to create pocket parks. Between 2015 and 2019, a total of 63 pocket parks (community green spaces, street gardens) were built. In 2020, 37 new pocket parks will be built.

The Guangzhou Pocket Park Design Guidelines report was issued to offer guidance on the design of pocket parks. Permeable pavement, tall trees, sunken green space, and native plant species were encouraged, along with shading public arts/structures. All these measures can enhance the cooling capacity of parks.



Guangzhou Pocket Park Design Guidelines

Source: Guangzhou Urban Planning & Design Survey Research Institute

Source: Guangzhou Urban Planning & Design Survey Research Institute

Parks are very important in high-density cities like Guangzhou. The small-scale green spaces and parks within Zhujiang New Town provide cooling effects among skyscrapers and also leave breathing spaces between concrete surface.

Smart surface: green, permeable and breathing

Water bodies

Priority: ★

There are many medium-size lakes and wetlands, as well as small-size ponds and pools in the city . The cooling effect of small- and medium-size bodies of water is not as prominent as that of large rivers, but they still play an important role in the UHI effect mitigation.

Strategy 1

Combine water bodies with vegetation to amplify the cooling benefits

When paired correctly, two urban cooling strategies can complement one another (Bloomberg Associates 2019). Water bodies and green infrastructure are ideal combinations of both cooling solutions and landscape design. When water features go hand-in-hand with the implementation of green infrastructure, the cooling benefits of both can be significantly amplified.

Actions

- Combine water bodies with green areas to form a networked area. Large parks are encouraged to be built around a water body, with a water-surface ratio of no less than 40%.
- Place the water bodies in the upper direction of the prevailing wind to bring cool air downward into the developing blocks.
- Use a natural revetment for water bodies to increase the variety of vegetation and improve the health of the ecosystem.

Strategy 2

Make use of the sponge city actions to maximize the passive evaporative cooling effects of water

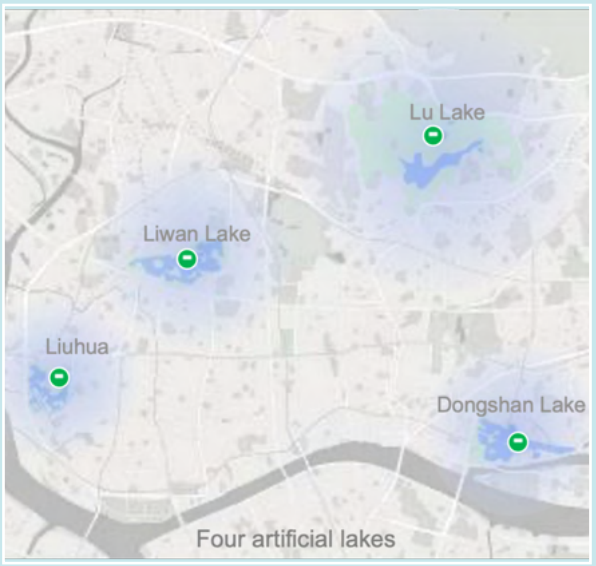
As Guangzhou has abundant rainfall in the summer, there is huge potential for the retention of rainwater in the landscape to maximize passive evaporation. However, when using this strategy, it is necessary to consider the negative impact of high humidity on human thermal comfort and other problems caused by stagnant water.

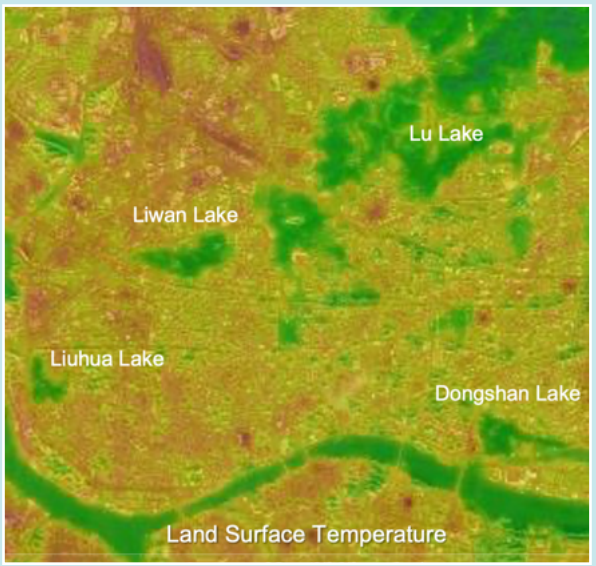
Actions

- Where possible, artificial lakes should be built to enhance the cooling effect of water bodies.
- The flow and storage of water should be designed at ground level rather than underground where possible.
- Use sunken green areas, rain gardens. and other sponge city facilities to collect rainwater.
- Carefully control the rainwater interception speed so that rainwater on the ground can evaporate in time, thus avoiding the collection of stagnant water.

Box 6. Construction of artificial lakes

Since 1950s, Lu Lake, Dongshan Lake, Liuhua Lake, and Liwan Lake, have been built in the central areas of Guangzhou. Recreational and leisure parks have been built around the waters following the idea of combining blue waters and green spaces. These four artificial lakes have formed important cool islands in the city center. Not only have they regulated the ecological environment in densely developed areas, but they have also provided residents with a comfortable space for activities during the hot summer months.





Source: LANDSAT Thermal Data, 2021

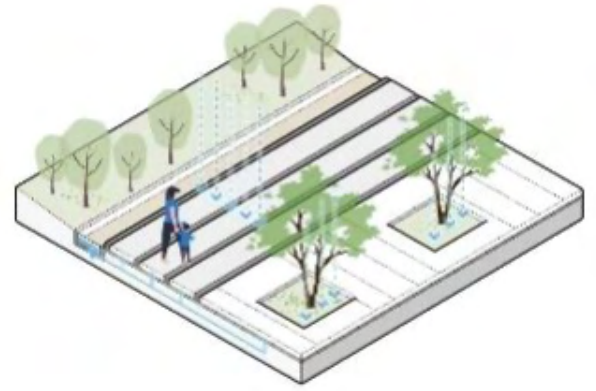
Source: Guangzhou Urban Planning & Design Survey Research Institute

Daguan Wetland Park demonstrates a successful conservation effort of water bodies in Guangzhou. Using its typical topography, there are many gravity-driven flowing water ponds scattered in the park. Luxuriant vegetation and ponds together create a significant cool island for central district.

Smart surface: green, permeable and breathing

Permeable ground surfaces

Priority: ★★



A permeable surface allows rainwater to penetrate into the soil. Water stored in the pavement can absorb a large amount of heat through evaporation and cool the pavement during summer, especially in a dry climate. Therefore, these pervious and porous materials not only improve stormwater management but also facilitate moisture evaporation more efficiently, offsetting the excessive heat released by conventional paved surfaces.

Strategy 1

Reasonably determine usage of permeable surfaces

Permeable pavements are man-made "breathing" surfaces with good economic and ecological benefits. They should be promoted in the city construction process, but they also have shortcomings, such as low load-bearing capacity and high maintenance costs, which make them not suitable for all urban space.

Actions

- Promote use for lower traffic areas such as no-vehicle roads, parking lots, alleys, or trails.
- For new development projects, establish mandatory requirements of permeable pavements. No less than 70% of the outdoor parking lot, pedestrian street, bicycle path and external courtyard of new developments shall be permeable paving.
- Expand the use of permeable pavements in renovation projects of old neighborhoods.
- Avoid usage in sites that may be easily polluted by the surroundings or may cause pollution to natural bodies of water.

Strategy 2

Conduct appropriate installation and maintenance to improve performance

The base layer of the permeable surface is crucial to its success. Careful vertical design and boundary space treatment can enhance its capacity to deal with stormwater. Since permeable materials are easily blocked by dust, dirt, salt, and garbage, proper maintenance is needed. (ESMAP, 2020)

Actions

- Balance the water permeability and load-bearing performance of the base layer to reduce surface damage from traffic pressure as much as possible.
- Use vertical design to direct water flow. Establish swales, rain gardens and other water collection facilities in the boundary space of the permeable sites to supplement stormwater collection capacity.
- Conduct regular cleaning to restore and enhance permeability.

Strategy 3

Select suitable permeable surface materials and techniques

Permeable paving includes porous and pervious materials (such as foam concrete, permeable asphalt, resin concrete), block pavers (such as grass block pavers), and paver spaces. The appropriate permeable surface materials and techniques should be selected based on the site characteristics.

Actions

- Porous and pervious paving materials can be combined with light-colored coatings and are most appropriate in low traffic playgrounds and biking pathways.
- Block pavers are permeable and filled with reflective materials or vegetation. They can be used in parking lots, driveways, and courtyards.
- Paver spacing creates permeability by creating small spaces between pavers, allowing rainwater to pass through and watering adjacent trees. This is most appropriate for sidewalks.

Smart surface: green, permeable and breathing

3D greening

Priority: ★★★

3D greening is an important form of urban greening. It is an effective way to provide similar benefits to trees and parks. In high-density urban areas where ground-level greenery may not be feasible, 3D greening becomes an important alternative to enrich the urban landscape and living environment.

Strategy 1

Encourage varying forms of 3D greenery to create an urban forest

3D greening should be introduced in many forms such as sky terraces, landscape decks, roofs, and walls. Luxuriant landscaping and greenery on structures and high-rises will create an urban forest where vegetation is harmonious with construction. The city would benefit greatly from a network of green spaces across different scales.

Actions

- Flat roofs on new buildings with less than 12 floors and a height of less than 40m should implement rooftop greening.
- A skyrise garden should be set up between the podium and the tower of new buildings.
- Encourage the reconstruction of existing building space to set up 3D greening.
- Integrate viaducts, overpasses and footbridges to create vertical greening.
- Ensure the continuity and connectivity of all the green spaces into one ecosystem network that spans all built surfaces. Connect sky terraces, rooftop gardens, natural ecology, and ground tree canopies to form a continuous "cool interface".

Strategy 2

Choose the best-suited type of green roof/wall for each project

Considering load-bearing requirements, structures, functions, cost-budget balance and other relevant factors, choose the most suitable type of green roof/wall.

Actions

- Extensive green roofs are more cost-effective for retrofitting existing roofs and low-slope roofs.
- Intensive green roofs are more complicated and costly with additional structural engineering for extra weight. These are better for flat roofs of new commercial architectures.
- Extensive green walls have low installation costs and maintenance, using ground planters and climbing plants such as vines. They are most suitable for low-rise buildings in historic and cultural district.
- Intensive green walls use modular, panel, tray or other support systems which require high maintenance. These are best suited to high-rise commercial buildings.

Strategy 3

Produce low-maintenance and self-sustaining 3D greening to ensure continuous use.

It is crucial to minimize the need and cost of maintenance for the success of 3D greening, so greenery should be easy to grow and self-sustain.

Actions

- Fully consider resistance to wind and drought, sunshine requirements, growth speed, coverage density and flowering cycle when selecting plant species for 3D greening.
- Set up a rainwater collection system for automatic irrigation, and install solar photovoltaic panels to power the irrigation and lighting systems to achieve maximum self-maintenance.
- Incorporate a variety of facilities, including urban farms, restaurants, cafes, and other amenities, to rooftop gardens, in order to ensure proper maintenance and use.

Box 7. Bridge greening in Guangzhou

Guangzhou is currently the city in China with the largest number of green bridges. Through continuous technical innovation and careful maintenance measures, it boasts the best bridge landscaping in China.

The 353 green bridges and over-passes in Guangzhou have become one of the city's most important calling cards.

Bridge greening has increased green coverage by more than 1 million m^2 and reduced surrounding air temperatures by up to 1.55°C.

Photo: Dreamstime.com

Overpass greening at the intersection

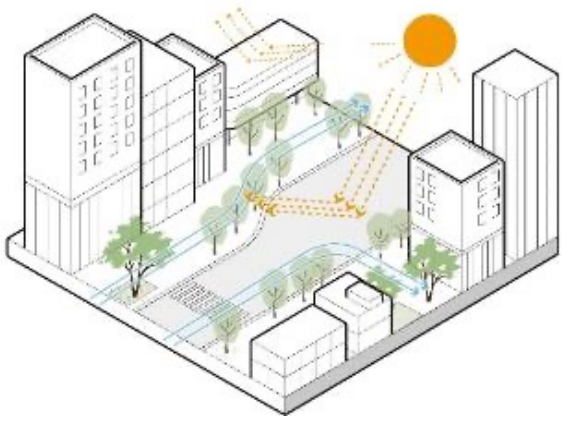
Source: Conghua Library

The Conghua Library inserts 3D greenery to cooling lanes, wind corridors, patios, and courtyards, which creates good natural ventilation conditions for the functional spaces of the building, improving the thermal environment and reducing energy consumption in the spring and autumn transitional seasons.

Smart surface: green, permeable and breathing

Solar reflective surfaces

Priority: ★★★



Highly reflective surfaces store and conduct less heat to its interior, in turn helping to reduce building energy consumption and heat waste from air conditioning use. Additionally, with cooler surfaces of the built environment, it can reduce urban ambient temperature and effectively improve human thermal comfort. The benefits of using highly reflective surfaces on urban buildings can be observed on individual buildings, building blocks, entire cities, and even on a global scale.

Strategy 1

Promote solar reflective roofs

Solar reflective roofs have been widely deployed in cities such as New York, but they are not very common in Chinese cities. With the advantages of simple installation, low cost, and proven benefits, this method can be developed through both voluntary incentives and mandatory requirements.

Actions

- Reflective roofs are most appropriate for flat and low-slope roofs, and they are not recommended for use on historical buildings.
- Prioritize the use of reflective roofs according to the thermal vulnerability of different areas.
- Establish standards of solar reflectance, thermal emittance, and solar reflectance indices for cool products.

Strategy 2

Pilot solar reflective pavements

Cool pavements are a promising cooling strategy for new towns with a large amount of roads and grounds. However, the technology is relatively new, and the longevity of cooling benefits are unknown, so a slow approach to taking reflective pavement coatings to scale is necessary (Bloomberg Associates 2019).

Actions

- Use reflective paving in pedestrian and low-volume traffic area on a piloting basis. This may be most effective when paving large, exposed areas, such as parking lots.
- Consider shipping costs, service life, and maintenance/reapplication costs when comparing between coating products.

Strategy 3

Control building façade colors

Cool walls are very similar to cool roofs, but they are applied to vertical building surfaces. The cooling effects can also be easily achieved by using light-colored coatings rather than special products. Since building facades are crucial to the citizens' visual perception, landscape effects, safety factors, and other objectives need to be considered when planning cool walls.

Actions

- Account for the factors of cooling capacity when designing an urban color plan.
- Encourage the use of highly reflective materials when renovating the façades of old neighborhoods.
- Promote light colors for façades in new building projects, combining urban cooling with landscape aesthetics.

Box 8. Color features of building façades in Guangzhou

In Guangzhou, the temperatures of red brick walls are 6°C higher than that of lime painted brick wall (Xiehao, 2004), Therefore, the external walls of the buildings have mostly been adorned with light-color bricks and grey tiles to adapt to the environment.

The use of light colors on the surfaces of traditional buildings can soften visual impact and create a community vibe, while also adding a sense of coolness and balancing psychological perceptions.

Light colored wall in old town

Smart facility: improve outdoor thermal comfort

Street networks

Priority: ★★

Street networks are the basic structure of the urban layout. Appropriate street grid patterns can promote air flow into the urban areas and mitigate urban heat.

Strategy 1

Select appropriate street grid patterns that are good for ventilation

The geometric shape and orientation of streets affect the amount of solar radiation received by the street surface and the airflow in blocks. Different areas can select different street patterns and orientations. Regular street patterns in some areas can create the wind channels along streets, and some irregular patterns can have lower canyon effects.

Actions

- Street orientation should align with the prevailing summer winds. The length of streets that are perpendicular to prevailing wind should be shortened as much as possible.
- Encourage the form of regular street grids, which allow easy organization of urban ventilation, shelter direct sunlight, and provide the best traffic efficiency.
- Narrow streets with tall buildings are effective in hot and dry climates, particularly with an aspect ratio (height/width of the street canyon) above 4. Thermal modelling of the urban fabric is encouraged to determine the proper balance between ventilation and shading.

Strategy 2

Regulate street density and building ground coverage

Generally, lower ground coverage and wider streets can increase the permeability at the pedestrian level. However, in a high-density city like Guangzhou, narrow streets and high-rise buildings can sometimes increase the shading effects.

Actions

- Promote dense street networks and UN-Habitat recommendations of at least 18 kilometers of streets per square kilometer (9 1-km streets by 9 1-km streets) with a maximum distance of 110m between adjacent streets.
- Limit the overall building coverage of the neighborhood. The overall building coverage of the blocks should be between 25%-50%.

Strategy 3

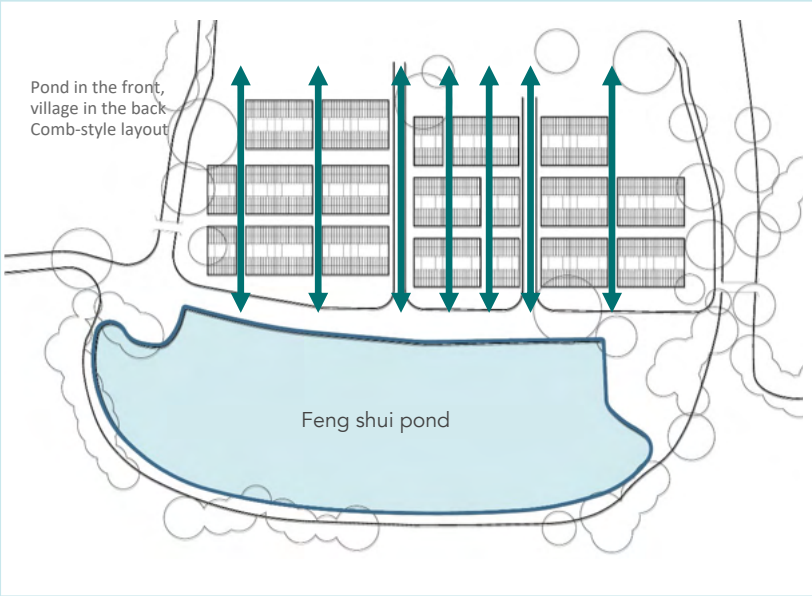
A comb-style layout and cool alleys are encouraged in old town regeneration

Considering the unique climate conditions of the Guangzhou region, special attention should be paid to the balance between ventilation and shading. Absorbing the local knowledge from Lingnan architecture, the layout of traditional neighborhoods can be integrated into the cooling system.

Actions

- In old town renewal, use horizontal streets as the main traffic linkages and connect with dense longitudinal lanes, driving the air flow between streets and lanes.
- Introduce a comb-style layout and build cool alleys in old village regeneration.

Box 9. Comb-style layout



The comb-style layout is typical of traditional villages in Guangzhou. Most of the villages are located in the north and face south. There are also often feng shui ponds sitting in front of the village.

Southeast monsoons are prevalent in Guangzhou in the summer, and the main lanes of the village are parallel to the prevailing summer wind. Therefore, the cool breezes across the pond can reach into the village along the comb-style alleys. These comb alleys serve as cool alleys. The villages here are mostly aligned from the east to the south. The front of the villages are low while the backs are high. This terrain is effective for water drainage. It can also direct the downward flow of the wind into the rear of the village. The high-density layout of traditional Guangzhou villages, with high walls and narrow alleys, is highly adaptive to the climate of the region. Most of the activity spaces are located in the shadows of buildings to reduce solar radiation. Gables extending outside of the building surfaces also offer shade from the rooftops.

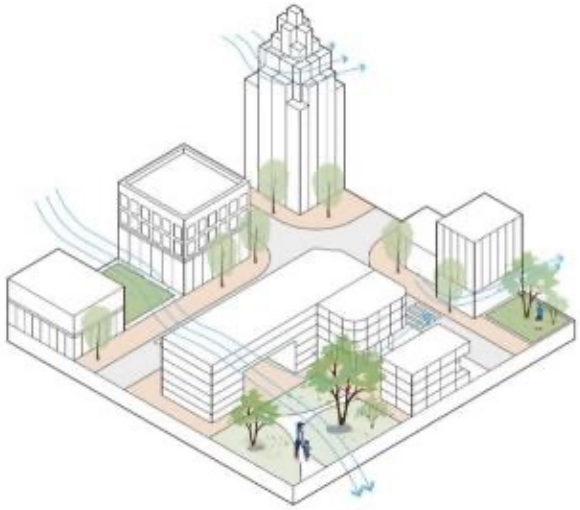
Photo: Lishi

Langtou village, which is located in Huadu district of Guangzhou, still maintains the traditional comb-style layout. With the water ponds (Feng shui Tang) at the front, narrow cool alleys can bring the winds flowing into village.

Smart design: maximize ventilation and shading

Architecture layout

Priority: ★★★



Architectural layout refers to the relationships between buildings. It includes the relationship between buildings and open spaces and the interrelationship between buildings and streets. The ventilation and shading closely relate to building heights, street width ratios, spatial position, alignment and orientation.

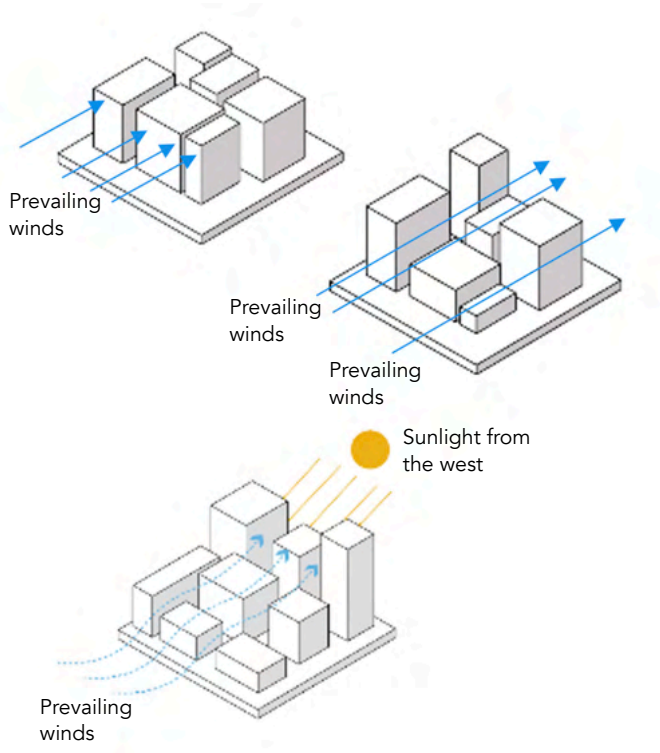
Strategy 1

Building height variation

The height layout of buildings offers shading for open spaces and influences wind flow. Varied building height could potentially contribute to the change of wind pressure and promote horizontal wind flows.

Actions

- Provide a layout with varying building heights. The height of buildings should gradually decrease along the prevailing winds.
- The highest buildings should be placed in the western part with the lowest buildings in the eastern and northern parts.



Strategy 2

Arrange a layout with an appropriate assemblage of buildings and open spaces

Most towns in Guangzhou are high density or consist of high-rise buildings. An appropriate layout of open spaces and buildings improves air flow inside the block. Building heights and shapes can be variable, and an appropriate assemblage should be integrated with a layout of open spaces. In some circumstances, buildings in irregular assemblage can support winds flow. Especially in newly built neighborhoods, layouts that follow wind and light paths are recommended.

Actions

- Set appropriate distances between buildings and avoid extensive elevation blocking air movement.
- Provide properly elevated structures.
- Pay attention to the interrelationship between buildings and open spaces and allow buildings to provide shading for open spaces.
- Integrate open spaces with ventilation corridors to facilitate air movement.
- Regulate building setbacks.
- Provide building interfaces that can facilitate ventilation.
- Main entrances of the block should be located in the southern, south-eastern, and eastern sides of the plot, operating as wind intakes. Air intakes should cover the entire block.
- Adopt a mixed layout to improve the wind environment by partially blocking or changing the angle of the layout and introducing wind into the enclosed space.

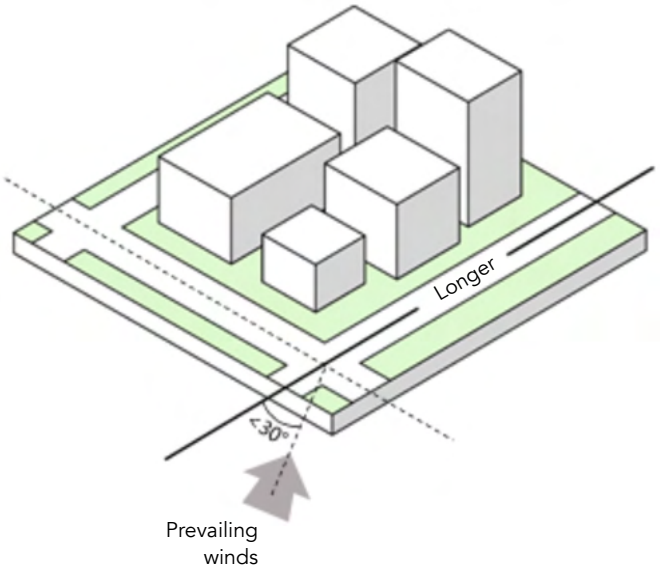
Strategy 3

Alignment and orientation of buildings should follow air movement paths

For the newly constructed buildings, choosing the appropriate orientation is very important. These actions could be included in new town construction and regeneration plans. Buildings should be aligned at the appropriate angle to the prevailing winds.

Actions

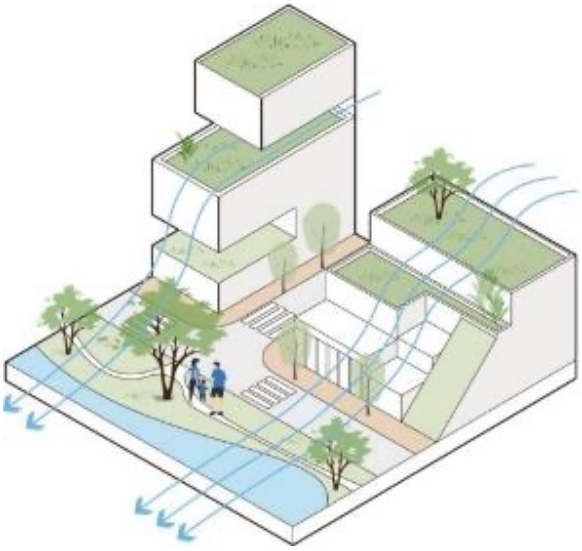
- Buildings located along the waterfront should be arranged at an angle that creates an inverted wide V shape with the prevailing winds from the river.
- The central axis of buildings should be parallel to the prevailing wind.



Smart design: maximize ventilation and shading

Architecture design

Priority: ★★★



Architectural design in these guidelines covers three main aspects: building ventilation, insulation, and shading. This strategy aims to provide appropriate building geometries to support wind flow, shading infrastructure, and thermal insulation.

Strategy 1

Architecture ventilation

Climate-resilient architectural design is important for natural ventilation. The permeable building geometries can contribute to air flow while improving thermal comfort inside the buildings.

Actions

- Create small-scale cooling zones around buildings through patios, cool alleys, stilts, and other passive ventilation architecture.
- In Guangzhou's case, it is more useful to infill the separated, small-scale gardens into a compact urban form.
- Incorporate the passive ventilation elements from Lingnan architecture, including Tanglong doors, window blinds, flexible doors, and windows.
- The building layout should follow the wind orientation and prevent building facades blocking wind flow.
- Slice buildings vertically to provide for cross ventilation. Control the thinness of buildings in less than 12 meters as 'one-unit thick' to provide for cross and stack ventilation.

Strategy 2

Architecture shading

The use of shading structures is important. Shading facilities are usually set up on building facades or rooftops. The use of cooling or sustainable materials should be considered as well. Additionally, natural landscape elements can also be used as shading infrastructure, especially tree shadows.

Actions

- It is recommended to use window blinds, grilles, and other building shading structures. Large glass curtain walls are not recommended.
- Rooftop shading facilities are recommended.
- Shading facilities should use materials without light pollution.
- The design of shading facilities in Guanghzhou should consider the solar altitude angle in the summer.

Strategy 3

Architecture insulation

Thermal insulation materials are useful in Guanghzou's climatic conditions. It is important to conserve and learn from traditional Lingnan buildings and apply those cooling techniques on new buildings. Double-deck walls or rowlock walls are usually used to cut off thermal transmission.

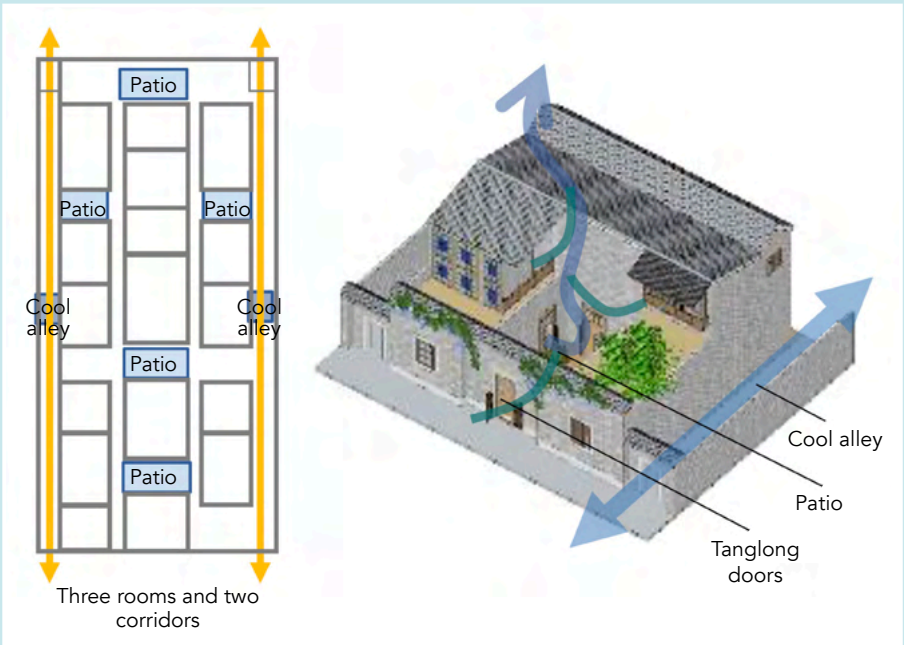
Actions

- Regeneration programs for old districts should preserve the thermal insulation design of traditional architecture.
- New materials, such as PCMs, can be integrated to improve the thermal insulation of buildings.

Box 10. Traditional Lingnan architecture

The three-room and two-corridor layout is a typical dwelling style of Guangzhou. It has three rooms in the main structure plus two corridors and a patio that sits in the north and faces south. Traditional Xiguan houses usually have 1-2 meter wide alleys on either side. It is called a Qingyun alley, which can be considered a cool alley contributing to ventilation.

In areas where space is limited, these buildings are constructed with bamboo tubes and structured with a narrow façade and a long depth. Ventilation and lighting can be achieved through high windows and side windows between the front and rear parts of these bamboo tube houses. A number of patios are designed in the longitudinal direction of the house to form a breezeway, creating a three-dimensional ventilation system.



Source: Guangzhou Urban Planning & Design Survey Research Institute

Using the principles of Lingnan architecture, the construction of Guangzhou Climate and Agrometeorology Center implements green building in a local, low-tech, and low-cost way.

- **The building is arranged in a north-south direction, and the western end is connected to the mountain so that the building has almost no west facade.**
- **Traditional Lingnan architecture elements, such as cool lanes, patios, open halls, and courtyards, are used to effectively organize.**
- **Green roofs at different elevations are connected to the natural slopes, so the natural landscape is extended into the building.**

Smart facility: improve outdoor thermal comfort

Shading structure

Priority: ★★★

Shading facilities are an effective intervention to improve outdoor thermal comfort. They are usually only used during the daytime, especially at noon, when the sun's angle is greatest. Generally, architectural design and urban geometric layout can create shading for open spaces.

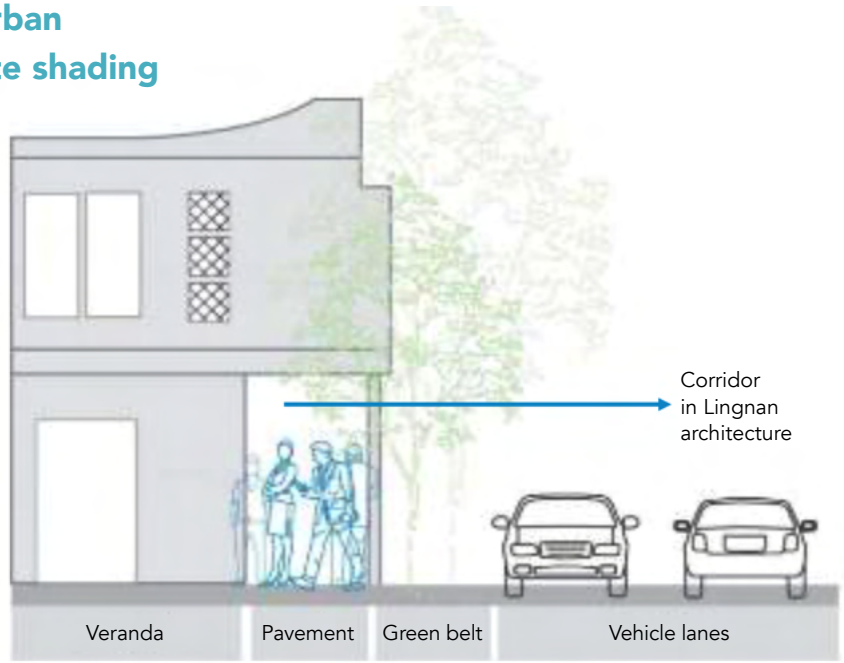
Strategy 1

Increase tree coverage and create a natural shading infrastructure

There are few cloudy days in the summer of Guangzhou. Introducing natural shading facilities, especially tree shadows, into public spaces in central areas can effectively address the impact of strong solar radiation. It is useful for pedestrian streets, large shopping malls, squares or central business districts, or densely populated old districts.

Actions

- Intensify trees with large canopies along streets to create comfortable walking spaces.
- Increase the vegetation coverage in open spaces.



Draw from the advantages of Lingnan architecture and use corridors and stilts

Source: Guangzhou Urban Planning & Design Survey Research Institute

Strategy 2

Install passive shading infrastructure and improve the thermal comfort of public spaces

Shading facilities will not reduce the temperature of the city itself. However, shading facilities can alleviate the outdoor thermal impact on pedestrians, thus changing the pedestrians' perception and enhancing the walking experience in high temperatures. Applying passive shading infrastructure through micro-renovation of buildings can greatly improve the comfort of public spaces.

Actions

- Increase shading facilities through architectural design.
- Introduce movable or fixed shading facilities based on immediate context.

Source: Guangzhou Urban Planning & Design Survey Research Institute

Ensure the correct width of shading infrastructure

Box 11. Shading corridors in Knowledge City

The first shading corridor system in Guangzhou, the China-Singapore Knowledge City shading corridor system, has been implemented on an incremental basis.

The China-Singapore Knowledge City planned to create a 29-kilometer shading corridor. These corridors were built within the 400-meter radius of the Knowledge City metro station. They connect subway stations to public and civic services, shopping centers, and residential areas, to create a comfortable and convenient walking experience.

Knowledge City wind and rain corridor in Huangpu District, Guangzhou. (Image from: China-Singapore Knowledge City Devlopment and Construction Office)

Knowledge City wind and rain corridor in Huangpu District, Guangzhou.

Source: Guangzhou Urban Planning & Design Survey Research Institute

Traditional Lingnan architectures can provide comfortable temperatures at the pedestrian level through its unique arcade design. This design not only supports air flow along the street but also creates shading areas.

Smart facility: improve outdoor thermal comfort

Misting facilities

Priority: ★★★

Misting facilities sprinkle very small water droplets at high pressure to lower the surrounding air temperature. Under different climate conditions, misting facilities can reduce the temperature of the surrounding environment by 5 to 15 degrees Celsius. It is common to set up high-pressure misting facilities or fountains in crowded areas.

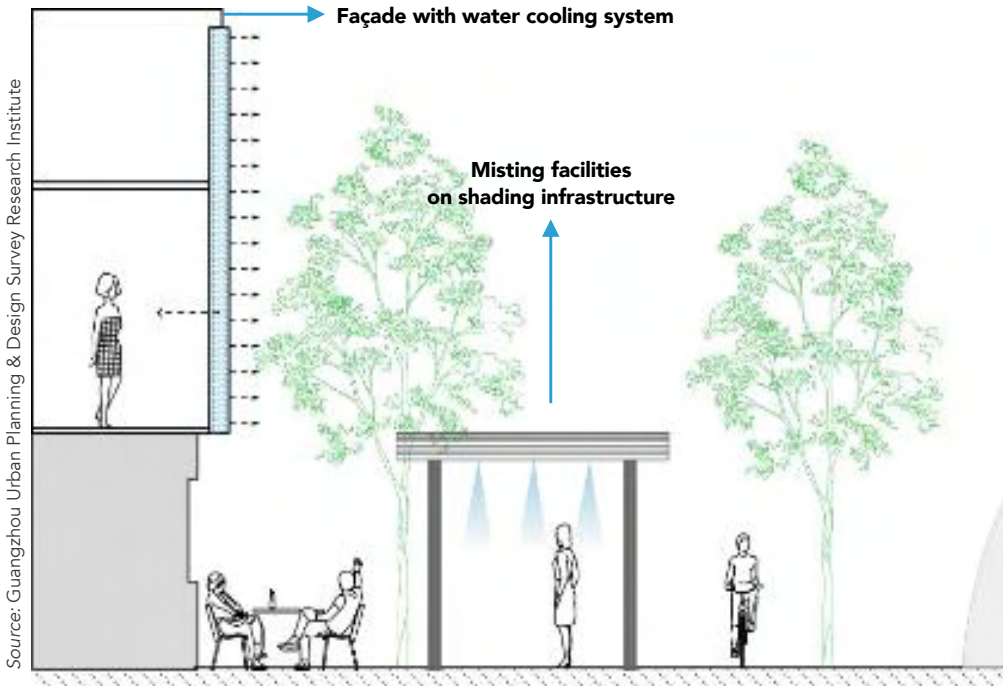
Strategy 1

Introduce water elements in urban landscape to achieve local cooling

Water is useful for densely populated city centers. Water elements can be integrated into the urban design to create water-friendly spaces. Additional spraying devices can also be installed under sheltered walkways to improve the comfort of walking.

Actions

- Use water features and fountains in urban design to enhance the outdoor thermal comfort effect.



Source: Guangzhou Urban Planning & Design Survey Research Institute

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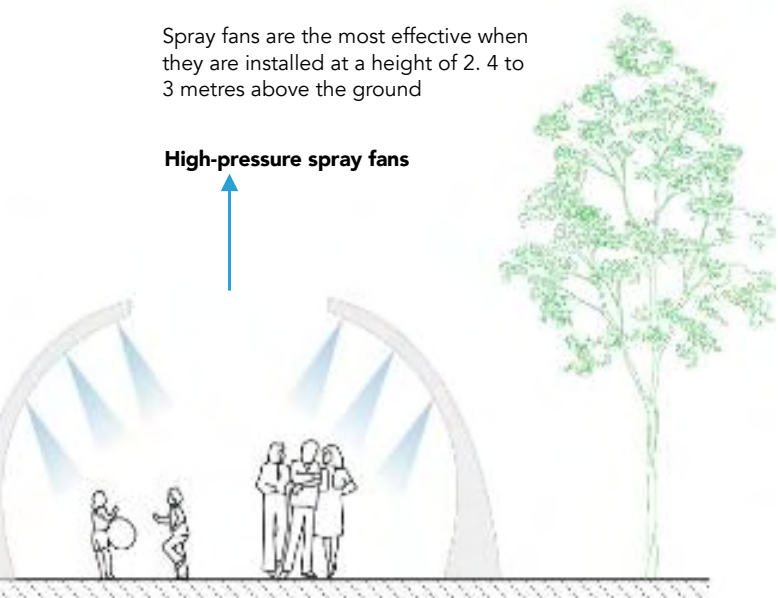
Actions

- Increase shading facilities through architectural design.
- Introduce movable or fixed shading facilities based on immediate context.

Box 12. Water elements used in public spaces: Design of a commercial plaza in CBD

Located in the central business district of Tianhe District, Parc Central is one of the city's largest commercial plazas. In addition to providing commercial services to the public, there are also open spaces that provide recreational services. A water-integrated landscape provides a comfortable space for visitors to relax and have fun.

Parc Central water-friendly facilities, Guangzhou



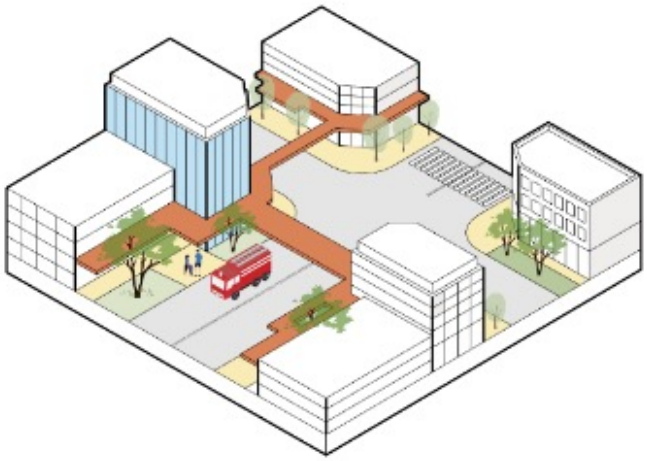
Source: Guangzhou Urban Planning & Design Survey Research Institute

Misting facilities are an effective passive cooling method in compact districts. While they cannot inherently change the local climate, misters can temporally change the surrounding temperature and further improve pedestrians' thermal comfort.

Smart energy: green transportation, efficient cooling

Green transportation

Priority: ★



Studies suggest that if the efficiency of an internal combustion vehicle is between 16-20%, almost all of the surplus energy from the fuel will be converted into heat, exacerbating the urban heat island effect. The amount of heat produced by vehicles is proportional to the amount of fuel consumed. Therefore, reducing transportation congestion and ensuring efficient traffic flow can reduce the heat caused by vehicles.

Strategy 1

Promote the use of public transportation

Guangzhou, as a mega-city, experiences immense daily traffic. Emissions from private vehicles are one of the most significant factors contributing to UHI Effects. Therefore, encouraging the use of public transportation and upgrading the traffic system can effectively reduce the use of private cars, traffic energy consumption, and heat emissions.

Actions

- Improve the infrastructure around transport stations and promote the accessibility of public transportation.
- Appropriately increase the cost of owning and driving private vehicles.
- Increase the integration and linkages between walking, cycling and public transportation routes.

Strategy 2

Develop a healthy mobility system and build a walking- and cycling-friendly city

In terms of demand, healthy transportation can be achieved by increasing the use of cycling or walking. It is useful for city centers with compact layouts, such as central business districts or interconnection nodes, to develop a healthy transport system that enables and encourages non-motor access routes.

Actions

- Apply separate cycling and walking lanes, and increase walking and cycling spaces across 50% of local roads.
- Increase pedestrian river-crossing trails to improve pedestrian accessibility on both sides of the Pearl River.
- Improve pedestrians' street experience through building facades, on-street facilities, and landscapes.

Strategy 3

Explore and promote energy-saving technologies

Improving transportation facilities and promoting the use of clean energy can reduce heat emissions. The improvement of transportation technology will generate long-term benefits.

Actions

- Promote electric buses to reduce heat emission from public transport.
- Encourage the use of electric vehicles.
- Build a centralized route planning platform with autonomous vehicles, which can not only ensure the appropriate vehicle scheduling, but also select best traffic routes, allowing smooth traffic flow.
- Introduce innovative, smart tech to integrate the green mobility system and increase its efficiency.

Box 13. Electric buses in Guangzhou

Buses are an important component of Guangzhou's public transportation system. Since 2017, Guangzhou has invested 14 billion RMB in electric buses. In a year's time, 10,486 electric buses went into operation, and 4,353 bus charging stations have been built. They have reduced both energy costs and emissions. The energy costs per 100-li is 31.1% lower than LNG-powered vehicles, 60.1% lower than LPG-powered vehicles, and 39.8% lower than diesel-powered vehicles.

Guangzhou wins C40 Cities Awards for green technology solution
(Photo: BRENT NG / AP IMAGES FOR C40)

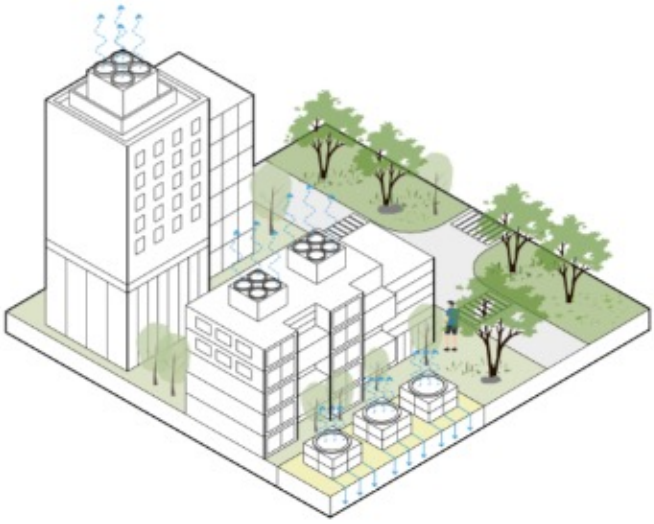
Photo: GuoZhongHua

Trams along the Pearl River are 100% electric. It greatly reduces the energy consumption while also lowering gas emissions.

Smart energy: green transportation, efficient cooling

Energy-efficient air conditioning

Priority: ★



Air conditioning is a common cooling method, especially for indoor cooling. The electricity use for air conditioners occupies a large proportion of a building's energy consumption. Therefore, improving the efficiency of air conditioning systems can lead to significant cost savings.

Strategy 1

Improve the energy efficiency of air-conditioning systems and reduce heat emissions

Currently, the indoor cooling in Guangzhou mostly relies on air conditioners. It is important to set the indoor temperature to an appropriate level without affecting the thermal comfort of residents. Increasing the pre-set indoor cooling temperature by 10°C can reduce energy consumption by 5%. Therefore, improving the efficiency of air conditioning systems can not only provide indoor comfort but also improve outdoor thermal comfort through reducing the heat released.

Actions

- Transform existing air conditioning systems with energy-efficient air conditioners. This will reduce energy consumption by 20-30% while achieving the same cooling effect.
- Set the indoor temperature to an appropriate temperature, and moderate air conditioner use to reduce heat pollution.
- Apply centralized district cooling infrastructure, especially in commercial districts and high technology concentrated districts.

Strategy 2

Encourage the use of indoor fans

The use of fans indoors in hot and humid regions can achieve effective cooling and increase the rate of evaporation. Integrating cooling fans into air conditioning systems can effectively save energy, reduce building heat emissions, reduce carbon emissions, and therefore mitigate the urban heat island effect.

Actions

- Increase the use of fans and, to some extent, shorten the length of time that the air conditioner is in use during the summer.
- Encourage the use of hybrid cooling systems combining natural ventilation, fans, and air conditioning, through the monitoring of sensors, actuators, and IoT systems, to significantly reduce cooling loads.

Box 14. The project of centralized cooling infrastructure at Huacheng Square

The underground district cooling system at Huacheng Square of the Zhujiang New Town is located beneath the riverside green belt of Linjiang Road. From the ground, it appears as only a 20-square-meter glass and steel structure hut. The cooling system can lower the temperature of the area by 2 to 3°C.

At the same time, it saves space on the ground level and eliminates landscape barriers. Using ice storage technology, coolers run at night during off-peak hours for electricity use and release their cooling capacity during the peak hours of electricity use in the daytime. This system achieves the separation of production and use of cooling capacity, thus achieving the goal of shifting peaks, making use of off-peak hours, and saving electricity.

The use of ground spaces at Huacheng Square

References

- Akbari, H., Levinson, R., Rosenfeld, A., and Elliot, M. (2009). Global Cooling: Policies to Cool the World and Offset Global Warming from CO2 Using Reflective Roofs and Pavements. Heat Island. Available at: http://heatisland2009. lbl.gov/docs/231200-akbari-doc.pdf.
- Bloomberg Associates (2019), "Mitigating Urban Heat Island Effects Cool Pavement Interventions," https://www.bbhub.io/dotorg/sites/32/2019/08/20190516_Cool-Pavement-Research-FINAL
- China Meteorological Administration (2020). Guangzhou Climate Bulletin 2020. Retrieved from: http://www.tqyb.com.cn/upload/admin/file/2021-02/2020年广州市气候公报.pdf
- ESMAP. 2020. *Primer for Cool Cities: Reducing Excessive Urban Heat*. Energy Sector Management Assistance Program (ESMAP) Knowledge Series 028/19. Washington, DC: World Bank
- Guangdong Provincial Center for Disease Control and Prevention (2020). Heat wave can increase the mortality by 4.8%. Retrieved from: http://cdcp.gd.gov.cn/ywdt/mtbd/content/post_3443632.html
- National Energy Information Platform (2020, August, 17). Response of China Southern Power Grid about the reason why Guangzhou reached rapid increase of electricity consumption. NetEase. Retrieved from: https://www.163.com/dy/article/FK8DH3KE05509P99.html
- Xie, H. (2004). The relationship between buildings' colour and climate adaptation. Building Energy Efficiency.
- Zheng, S., Huang, G., Zhou, X., & Zhu, X., (2019). Climate-change impacts on electricity demands at a metropolitan scale: a case study of Guangzhou, China. Applied Energy.

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