Research of Urban Heat Island (UHI) in Shenzhen

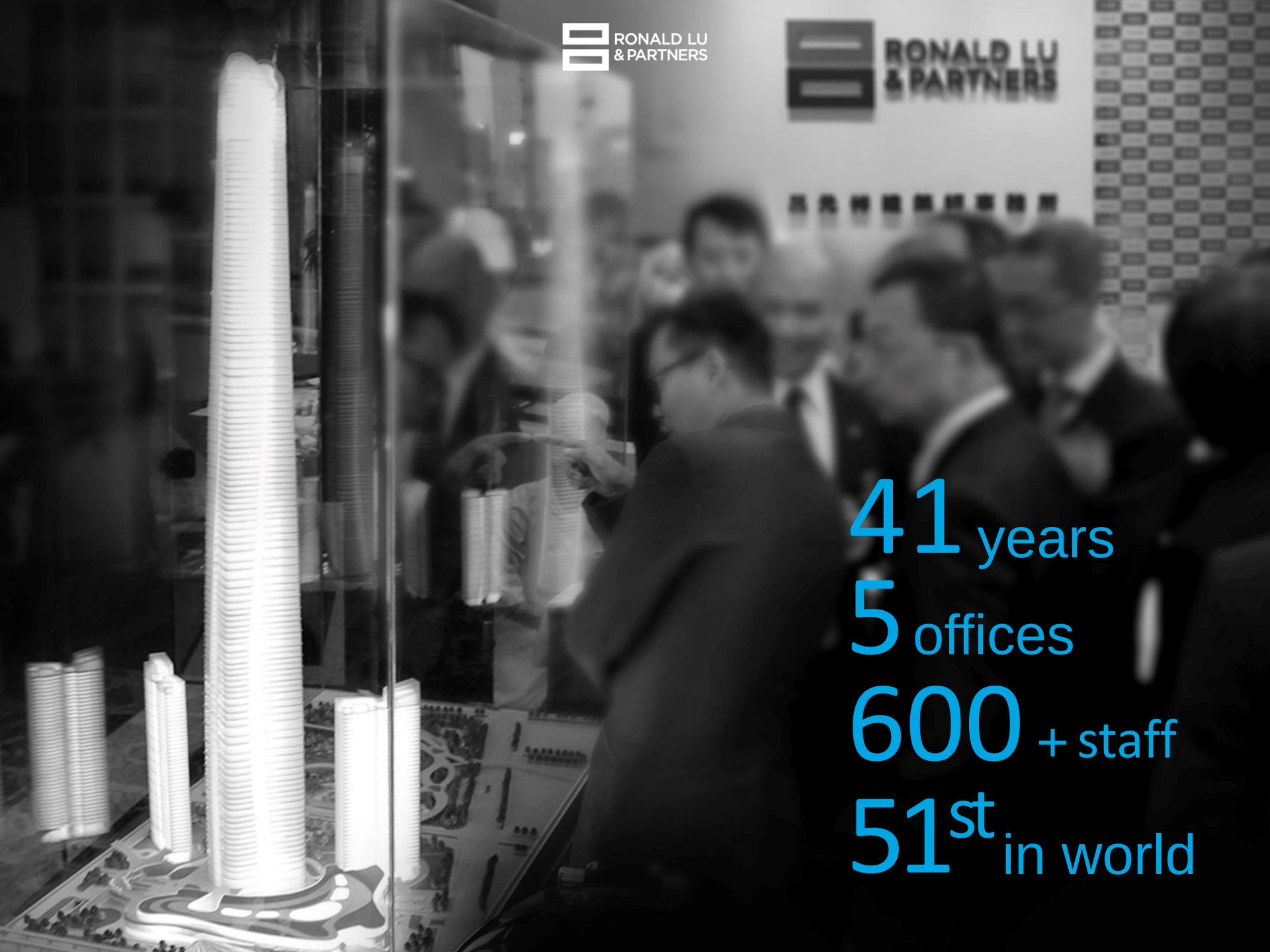
based on Climatic Design and Urban Planning Strategies

presented by:
Yu Wen Juan, Jenny
Ronald Lu & Partners

HONG KONG WORLD SBE 2017
WORLD Sustainable Built Environment Conference

Organisers:
CONSTRUCTION INDUSTRY COUNCIL 建造業議會
HKGBC 香港綠色建築議會

International Co-owners:
SBE SERIES
CIB
iiSBE
UNEP Sustainable Buildings and Climate Initiative
FIDIC
Global Alliance for Buildings and Construction


RONALD LU
& PARTNERS
RONALD LU
& PARTNERS
41 years
5 offices
600 + staff
51st in world

RONALD LU & PARTNERS

Contest

Introduction
UHI Issue of Shenzhen
Urban Planning Strategies to Control UHI
Conclusion

RONALD LU & PARTNERS

Introduction

GEOGRAPHY & CLIMATE CONDITION OF SHENZHEN

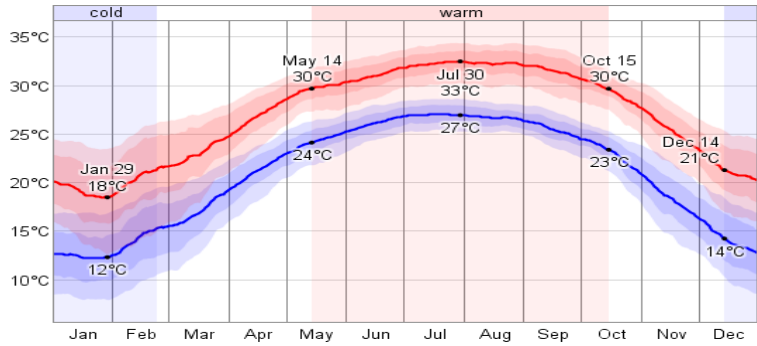
Topography

Southeast part	Hilly with mountains
Northwest part	Low along the west coast
Land use	Cropland, woodland, built up area, water body
4 major River	Maozhou, Guanlan, Longgang and Pingshan River

Climate

Hot summer and warm winter climate zone	
Humid subtropical marine monsoon climate	
Annual mean temperature	22.55°C
Monthly averages temperature	11.7°C in January to 32.2°C in July
Sunshine	1933 hours per year

Geographical environment of Shenzhen
(Source: Mapbox)



Climate data for Shenzhen (1971–2000) [hide]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	29.1 (84.4)	28.9 (84)	32.0 (89.6)	34.0 (93.2)	35.8 (96.4)	36.9 (98.4)	38.7 (101.7)	37.1 (98.8)	36.9 (98.4)	35.2 (95.4)	33.1 (91.6)	29.8 (85.6)	38.7 (101.7)
Average high °C (°F)	19.7 (67.5)	19.7 (67.5)	22.7 (72.9)	26.3 (79.3)	29.3 (84.7)	31.1 (88)	32.2 (90)	32.0 (89.6)	31.2 (88.2)	28.9 (84)	25.1 (77.2)	21.5 (70.7)	26.6 (80.0)
Daily mean °C (°F)	14.9 (58.8)	15.5 (59.9)	18.7 (65.7)	22.5 (72.5)	25.7 (78.3)	27.8 (82)	28.6 (83.5)	28.2 (82.8)	27.2 (81)	24.7 (76.5)	20.4 (68.7)	16.4 (61.5)	22.55 (72.6)
Average low °C (°F)	11.7 (53.1)	12.7 (54.9)	16.0 (60.8)	19.9 (67.8)	23.2 (73.8)	25.2 (77.4)	25.7 (78.3)	25.5 (77.9)	24.3 (75.7)	21.6 (70.9)	17.1 (62.8)	12.9 (55.2)	19.6 (67.4)
Record low °C (°F)	0.9 (33.6)	0.2 (32.4)	3.4 (38.1)	8.7 (47.7)	14.8 (58.6)	19.0 (66.2)	20.0 (68)	21.1 (70)	16.9 (62.4)	9.3 (48.7)	4.9 (40.8)	1.7 (35.1)	0.2 (32.4)
Rainfall mm (inches)	29.8 (1.173)	44.1 (1.736)	67.5 (2.657)	173.6 (6.835)	238.5 (9.39)	296.4 (11.669)	339.3 (13.358)	368.0 (14.488)	238.2 (9.378)	99.4 (3.913)	37.4 (1.472)	34.2 (1.346)	1,966.3 (77.413)
Avg. rainy days (≥ 0.1 mm)	7.07	10.07	10.77	12.73	15.60	16.47	17.00	16.30	14.83	7.63	5.63	5.97	144.07
% humidity	71.7	76.8	79.5	81.0	81.7	81.8	80.5	81.8	78.8	72.4	68.4	67.1	76.8
Mean monthly sunshine hours	147.9	93.8	101.4	110.2	149.8	173.6	220.0	188.6	181.2	199.5	184.3	178.5	1,933.8
Percent possible sunshine	44	31	27	29	37	43	53	47	49	55	56	53	43.7

Source: Shenzhen Meteorological Bureau[37]

Climate data for Shenzhen
(Source: Weather Spark & China Meteorological Administration)

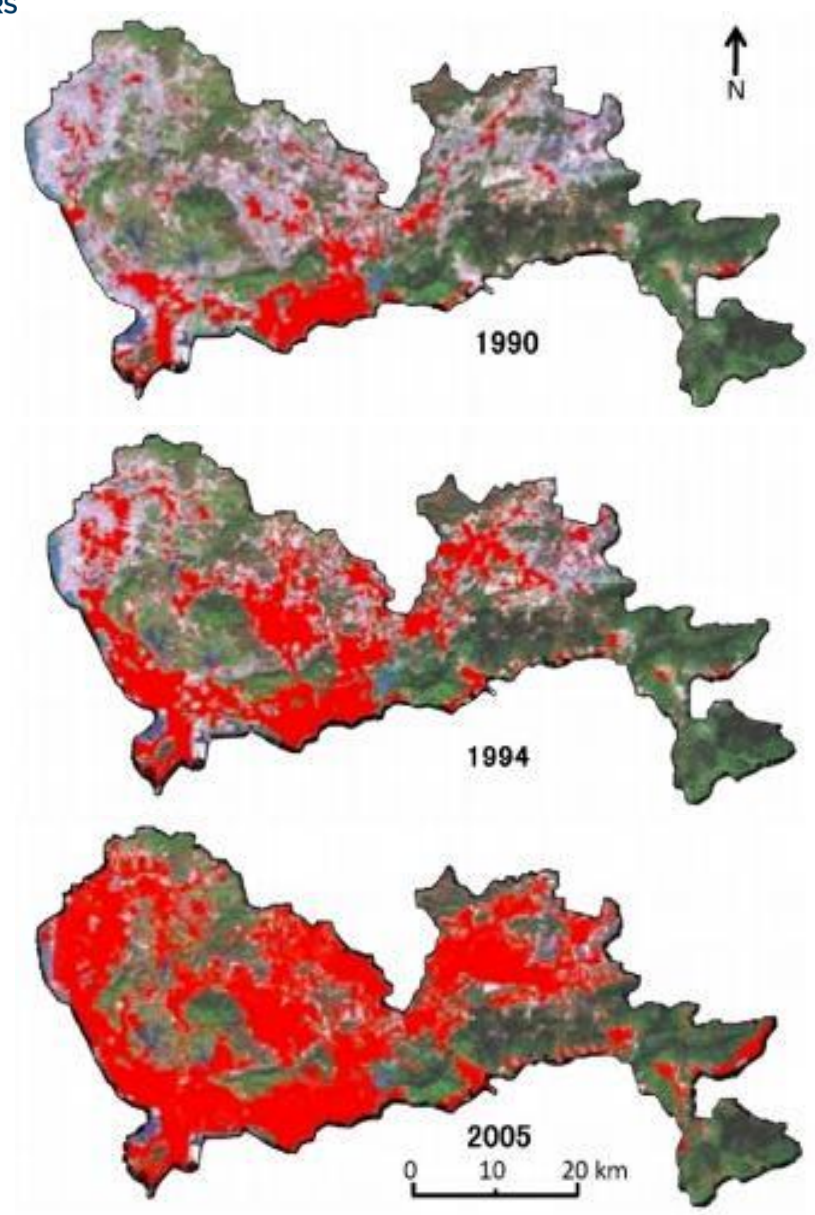
URBANIZATION DEVELOPMENT OF SHENZHEN

Population (1979 – 2010)

1979	0.31 million
2001	4.69 million
2010	10.37 million

Urbanization (1990 – 2005)

Built up space	↑ increased from 0.63% to 33.42%
Forest	↓ decreased from 38.71% to 29.96%
Water bodies	↓ decreased from 7.41% to 5.64%
Wetland	↓ decreased 0.21%



Urbanization Pattern in Shenzhen
(Che, et al., 2011)

RONALD LU & PARTNERS

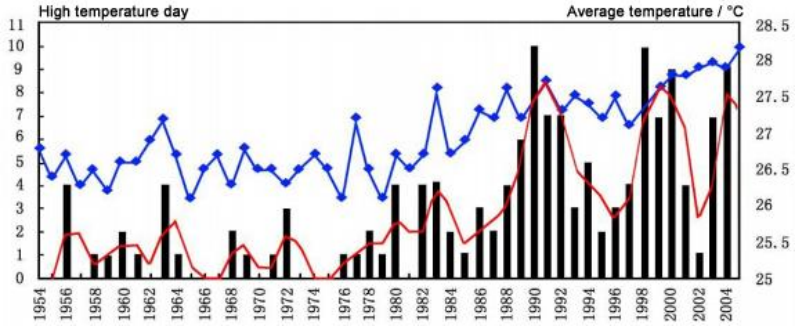
UHI Issue of Shenzhen

SPECIAL DISTRIBUTION OF UHI IN SHENZHEN

Temperature Change

Keeping increasing during the past 50 years and reaching 28 °C in 2005.

Temperature in the city center is approximately 3 °C higher than the suburban area.



Temperature in Shenzhen (1954 – 2005) (Lin, 2011)

Special Distribution

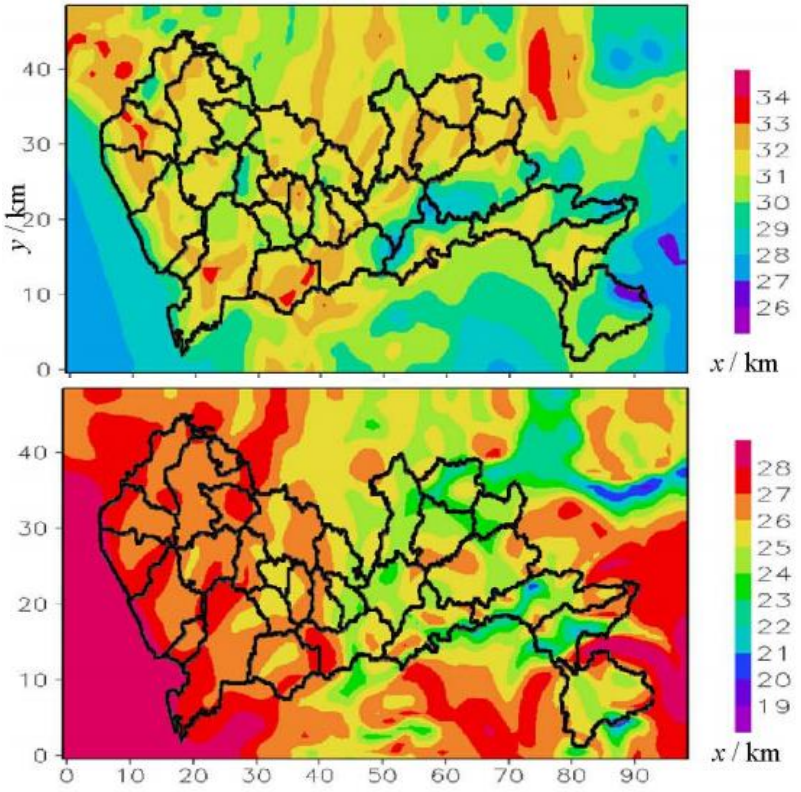
Daytime

Nanshan, Futian and western Bao'an district with temperature higher than 33 °C.

Other part with temperature between 31 °C to 33 °C.

Nighttime

City center with high density in western Nanshan, western Luohu and western Bao'an district with temperature more than 27 °C.



Air Temperature during daytime and nighttime (ZHANG, et al., 2011)

THE FORMATION OF UHI IN SHENZHEN – LAND USE CHANGE

Urban Land Expansion

UHI spatial distribution is highly match the urban land expansion pattern.

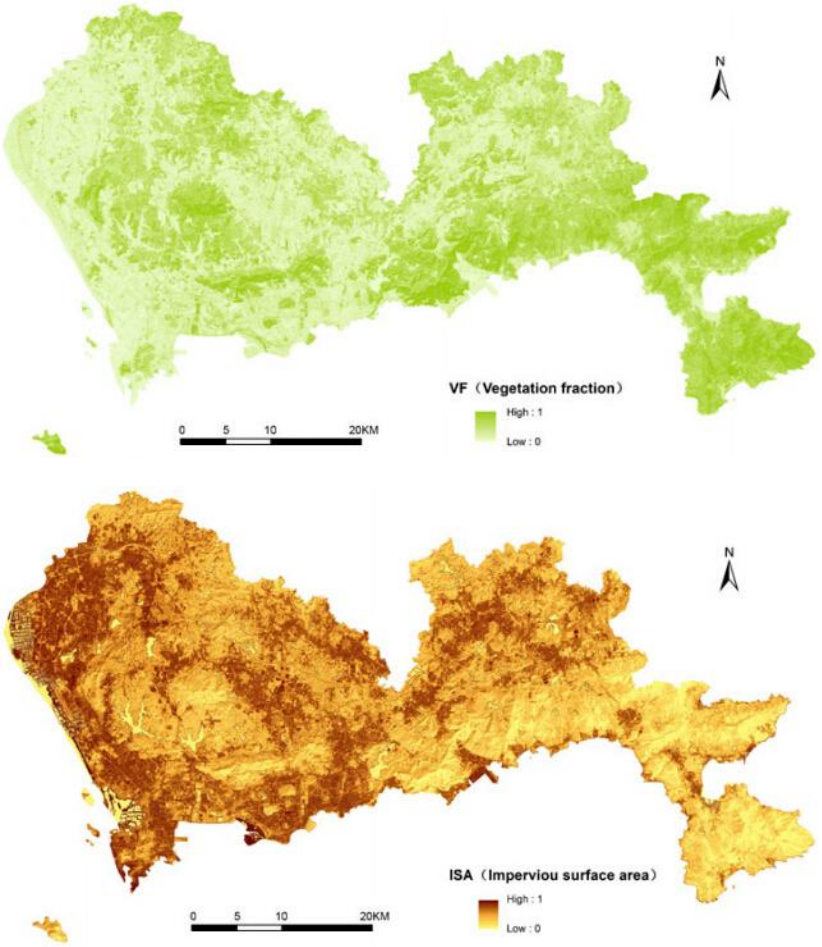
Constructed land will increase the surface roughness and have relatively high surface temperature thus generate UHI in this areas.

Reduction of Green Space

Land cover and landscape patterns are the two main factors that influence the LST.

The higher vegetation fraction areas the lower surface temperature.

The higher value of impervious surface areas the higher the surface temperature due to the cooling effect of the vegetation.



Vegetation fraction (VF) and impervious surface areas (ISA) in Shenzhen
(Xie, et al., 2013)

THE FORMATION OF UHI IN SHENZHEN – HIGH DENSITY BUILT UP AREAS

Lack of Greenery

With rapid urbanization and urban expansion, Shenzhen is toward a high rise and high density city like Hong Kong.

Street network is closely linked to each other without space for urban greenery.

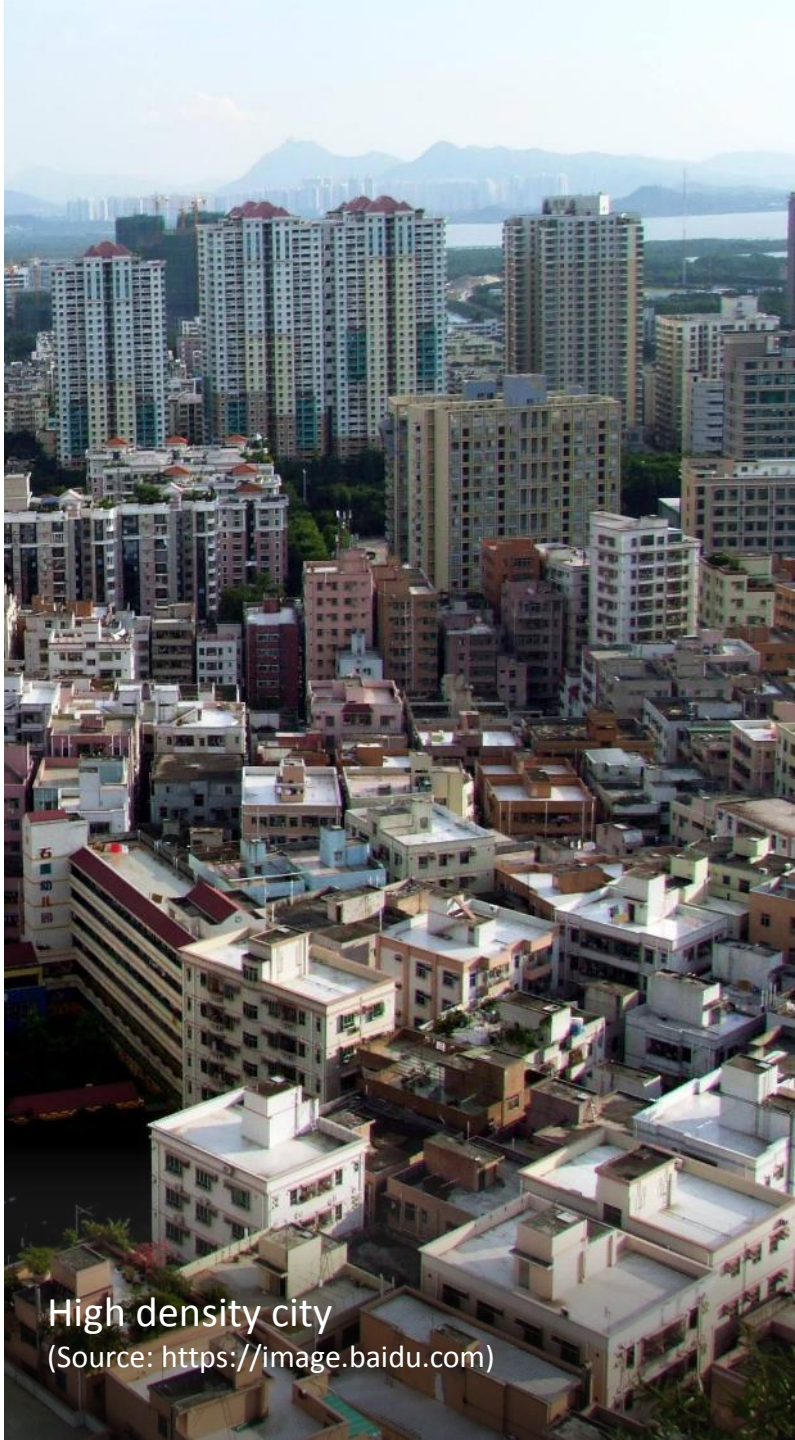
Planting of greenery cannot catch up with the urban construction.

Existing trees planted along the streets are too small to effectively cool down the district.

Poor Natural Ventilation

Wind speed will decrease from 2.7m/s to 1.2m/s when entering the urban districts.

Low wind speed with only 1m/s or even create stagnate zones in most areas.



High density city
(Source: https://image.baidu.com)

THE FORMATION OF UHI IN SHENZHEN – REDUCTION OF WATER BODIES

Decrease of River Network

The river network of Shenzhen has toward a decrease from 1980 to 2005.

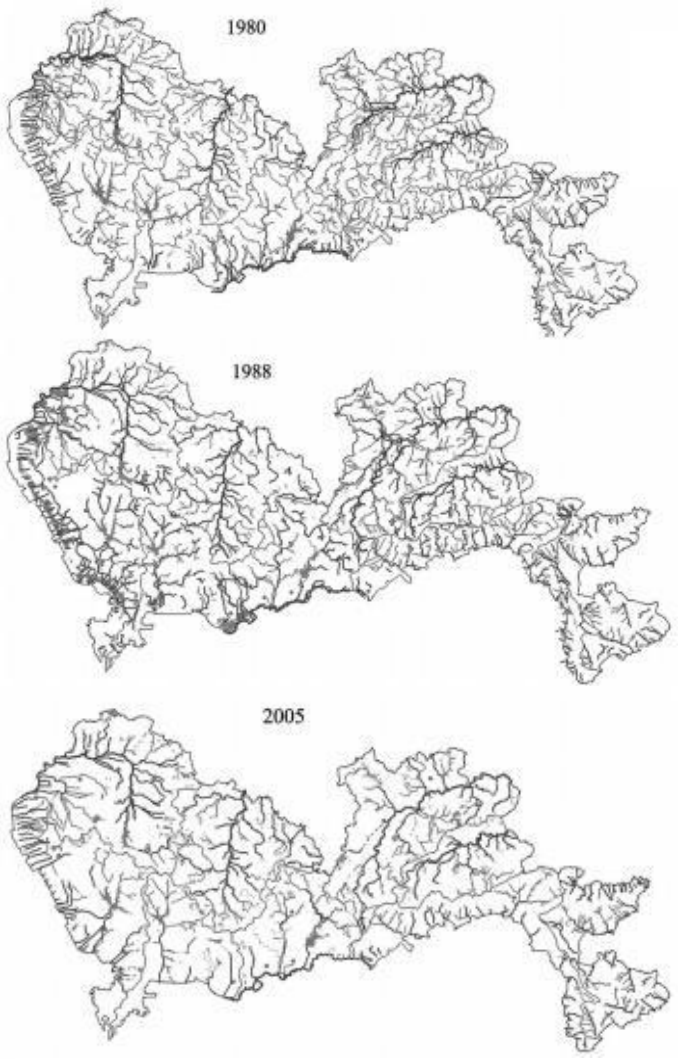
River network complexity is decreased from 36.1 to 31.6.

The number and length of the river are also decrease.

The total length of the rivers in Shenzhen shortened 355.4km.

Water bodies have been influenced by the urban development and the cooling effect of the rivers are also reduced.

In this case, the surface temperature is keep increasing with the decrease of water bodies therefore generate the UHI effect.



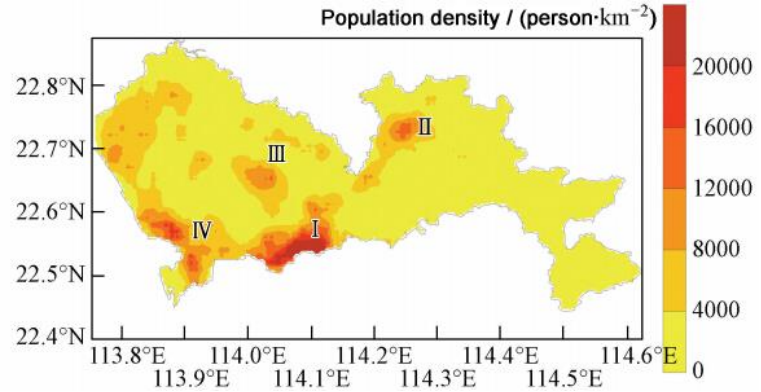
River Network Change in Shenzhen
(Zhou, et al., 2010)

THE FORMATION OF UHI IN SHENZHEN – ANTHROPOGENIC HEAT

Population Density

The UHI distribution pattern shows that the strongest UHI areas appear with high population density.

Human's activities will significant increasing the energy consumption thus generate unwanted heat of those regions.



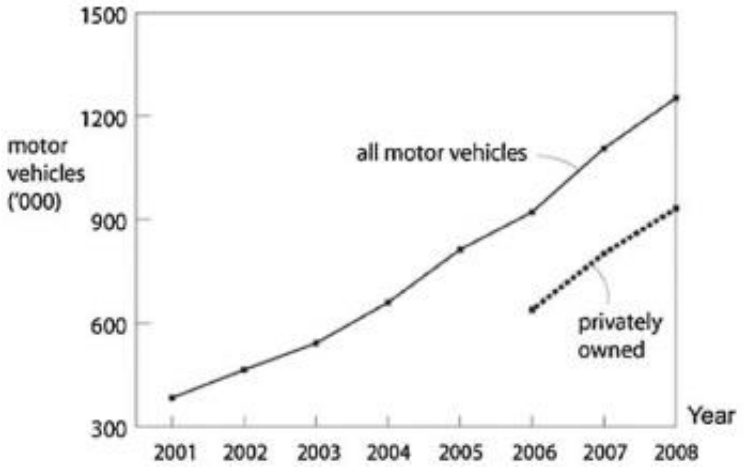
Population Density of Shenzhen
(Zhang, et al., 2011)

Emission of The Private Cars

The total number of motor vehicles and private car are increasing.

Reaching 2.72 million in 2014 with the annual growth rate of 16.2%.

The vehicle density is 440 per km which is much higher than the international standard.



Motor Vehicle and Private Car Tendency in Shenzhen
(Zacharias & Tang, 2010)

RONALD LU & PARTNERS

Urban Planning Strategies to Control UHI

VENTILATION CORRIDORS

City Scale

Follow the dominate wind direction of Shenzhen, the wind path should be arranged northeast to southwest and northwest to southeast.

Wind corridors may follow the major roads and green lands and link to each other.

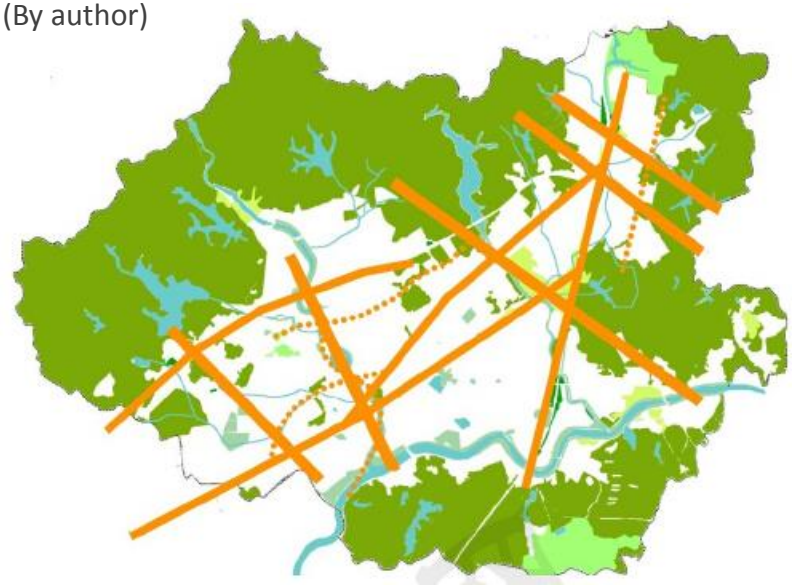
Be long and width enough to effectively ventilate the whole community.

Ventilation corridor on city scale of Shenzhen
(By author)

District Scale

A new district known as the Low Carbon City locates in Pingdi district represent the future urban planning model of Shenzhen.

Wind corridors are designed according to the dominate wind direction to reduce UHI effect.



Ventilation corridor on district scale
(XU, 2013)

LINKAGE OF OPEN SPACE AND INCREASE GREENERY

City Scale

Greenway has been built up which went through the whole city to increase greenery and bring wind into the urban construction areas.

Surrounding urban areas can be benefit from the greenway and reduce the temperature.

District Scale

Buildings setback to widen the streets.

Open spaces are design within the high density built up areas.

Trees are planting at the pedestrian level.

Green belts are closely linked with the surrounding nature land to make sure the cooling effect.

In some really high dense areas, vertical planting and roof gardens are provided

Greenway design in Shenzhen
(Source: http://www.google.com.hk)

RONALD LU & PARTNERS

BUILDING DESIGN TOWARD SUSTAINABLE URBAN PLANNING

Building Orientation and Disposition

Building should be oriented to face the prevailing wind.

The length of building façade along with the prevailing wind should be longer to reduce stagnant zone behind the building.

Building Height

A mix of low-rise and high-rise building will benefit the wind movement.

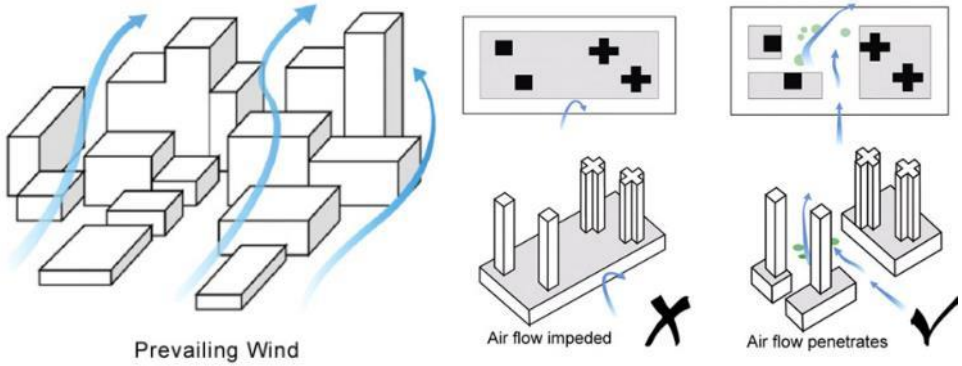
Increase the building height of the behind building along with the prevailing wind direction to enhance the ventilation.

Building Permeability

Better ventilation pattern can be achieved by creating gaps and openings on the buildings.

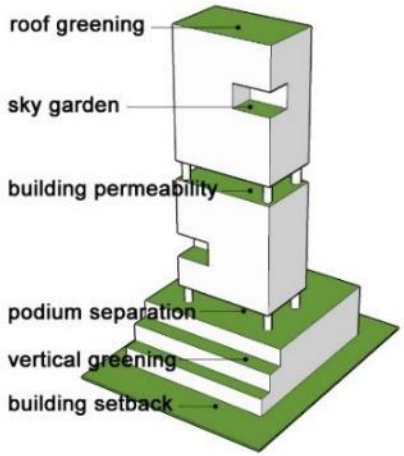
Building Height and Podium Separation

(HK Planning Department, 2014)



Building Permeability

(By author)



GREEN TRANSPORTATION SYSTEM

Green Subway System
Electric Vehicles
Public Transportation

The number of private cars can be greatly reduce therefore the anthropogenic heat generate by cars can also decrease, thus make great contribution to the control of urban heat island effect in Shenzhen.

Green transportation

(Source: https://www.google.com.hk)

RONALD LU & PARTNERS

Conclusion

RONALD LU & PARTNERS

PLANNING FOR FUTURE

Current

- Land use change during the urbanization process
- High density built up areas
- Reduction of water bodies
- Anthropogenic heat generated by human activities

Future

- Build up ventilation corridors
- Linkage of open space and increase greenery
- Building design toward sustainable urban planning
- Green transportation system

Sustainable urban planning
(Source:http://column.chinadaily.com.cn/article.php?pid=12310)

RONALD LU & PARTNERS

References

[1] Chen, J., Chang, K. T., Karacsonyi, D., & Zhang, X. (2014). Comparing Urban Land Expansion and its Driving Factors in Shenzhen and Dongguan, China. Habitat International, 43, 61-71.

[2] Che, X., English, A., Lu, J., & Chen, Y. D. (2011). Improving the Effectiveness of Planning EIA (PEIA) in China: Integrating Planning and Assessment During the Preparation of Shenzhen's Master Urban Plan. Environmental Impact Assessment Review, 31(6), 561-571.

[3] Huasheng, S. (1991). Urban Development in Shenzhen SEZ. Habitat International, 15(3), 25-31.

[4] Lin, Mengdie. (2011). Research on Thermal Environment Improve Strategy in Heat Island District of Shenzhen Futian Based on Computational Fluid Dynamics. Shenzhen Graduate School.

[5] Ng, M. K. (2003). Shenzhen. Cities, 20(6), 429-441.

[6] Song, B., & Somasundaram, S. (2009). Country Report on Building Energy Codes in China. Springfield, VA: Pacific Northwest National Laboratory.

[7] Shi, P., & Yu, D. (2014). Assessing Urban Environmental Resources and Services of Shenzhen, China: A Landscape-based Approach for Urban Planning and Sustainability. Landscape and Urban Planning, 125, 290-297.

[8] Tianhong, L., Wenkai, L., & Zhenghan, Q. (2010). Variations in Ecosystem Service Value in Response to Land Use Changes in Shenzhen. Ecological Economics, 69(7), 1427-1435.

[9] Wang, H., Shi, S., & Rao, X. (2013). A Study of Urban Density in Shenzhen.

[10] Xie, M., Wang, Y., Chang, Q., Fu, M., & Ye, M. (2013). Assessment of Landscape Patterns Affecting Land Surface Temperature in Different Biophysical Gradients in Shenzhen, China. Urban Ecosystems, 16(4), 871-886.

[11] Xie, M., Wang, Y., Fu, M., & Zhang, D. (2013). Pattern Dynamics of Thermal-environment Effect During Urbanization: A Case Study in Shenzhen City, China. Chinese Geographical Science, 23(1), 101-112.

[12] ZHANG, X. L., Lei, L., Yan, D., JIANG, Y., Xiaoyi, F., Mei, L., Yuan zhao & Yujie, B. (2011). A Numerical Study on the Influences of Urban Planning and Construction on the Summer Urban Heat Island in the Metropolis of Shenzhen. Journal of Tropical Meteorology, 17(4).

[13] Zhou, H., Shi, P., Wang, J. A., Yu, D., & Gao, L. (2010). Rapid Urbanization and Implications for River Ecological Services Restoration: Case Study in Shenzhen, China. Journal of Urban Planning and Development, 137(2), 121-132.

[14] Zhang Lijie, Li Lei, Jiang Yin, Tan Ming Yan & Li Hui. (2011). A Study of the Urban Heat Island in Shenzhen Based on Data from Automatic Weather Stations [J]. Climatic and Environmental Research (in Chinese), 16(4): 497-486.

[15] Zacharias, J., & Tang, Y. (2010). Restructuring and Repositioning Shenzhen, China's New Mega City. Progress in Planning, 73(4), 209-249.

WWW.RLPHK.COM

rlphongkong

呂元祥建築設計