



南開大學  
Nankai University



# Smart Urban Management

Zhou Enlai School of Government  
Digital Urban Governance Laboratory  
Computational Social Science Laboratory

Xuan SUN

# Content

- **Concept** development and innovation
- **Technology** application and improvement
- **Scientific** research and exploration
- **Computational** modeling and optimization



# Concept development and innovation

# Urbanization



In the 21st century, countries around the world, especially in **Asia** and **Africa**, are experiencing unprecedented rapid urbanization.

- Now, more than **55%** of people live in urban areas, and by 2050, this number will increase to **68%**.

——"World Urbanization Prospects 2018"  
the United Nations

- More and more **megacities** are popping up around the world.....It is predicted that by 2030, there will be **43 megacities** in the world with a population of more than 10 million.

Urban management become an important field of public management.

# Urban function change

## ■ “Athens Charter”

1933, the International Congress of Modern Architecture (CIAM) drew up the “City Planning Outline” in Athens.

### **Four basic function of city:**

Dwelling, Work, Recreation, Transportation

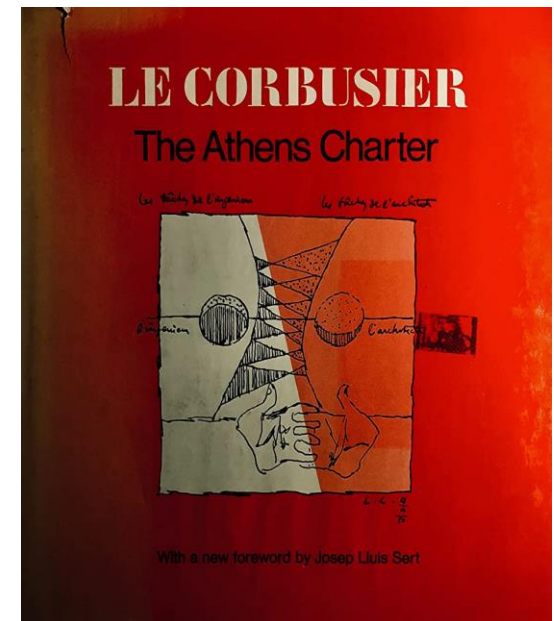
### **New function demands:**

Emergency response, Public services, Innovation

Coordination between construction and protection

Coordination between city and region

Harmony between human and nature



# Sustainable, healthy, learning city



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China  
 India  
 Philippines  
 Bangladesh

South Africa  
 Rwanda  
 Tanzania



## PARTNER ORGANISATIONS



Our interdisciplinary research and capacity-strengthening activities will move debate from an emphasis on the physical and environmental aspects of 'sustainable cities' towards a deeper understanding of how rapid urbanisation and increasing migration is impacting the social and economic sustainability of neighbourhoods within cities.



# Urban problems



**Population**



**Transportation**



**Housing**



**Environment**

# Problem-oriented urban management

Theory and experience can only guide the direction, but cannot directly solve problems

- cooperative governance, polycentric management, holistic management, ...
- regulatory governance, agile governance, good governance ...

Different cities have different economic backgrounds, social structures, and urban textures



How to deal with the practical problems in different cities?



# Big data era



**Office automation (business data)**



**Social media (communication data)**



**Urban IoT (environment data)**



**Smart card (daily life data)**

# Urban management with big data



IoT, Cloud computing & Office automation, Digital economy

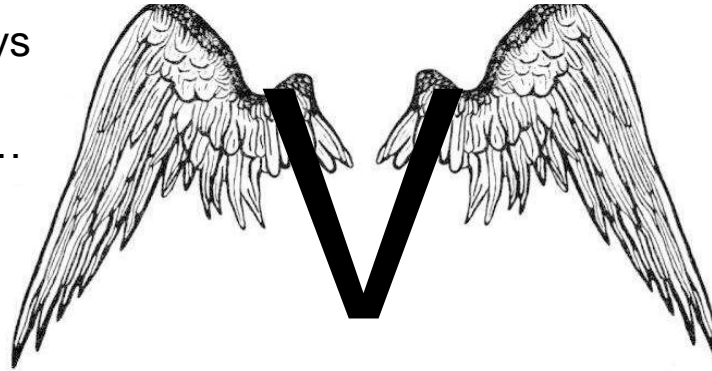


**Big data flow**

# Thinking innovation: 4M thinking mode

For big data, we always emphasize "V", and proposed 3V, 4V, 5V ...

Focusing on the **intrinsic features** of big data



**Volume:** large amount  
**Variety:** various sorts  
**Value:** low value density  
**Velocity:** fast generation  
**Veracity:** weak reliability

Result in: **learning and imitation** is far greater than the **effective use** of data resources

From the perspective of decision-making, we should have **4M thinking**

- **Microscope:** the detailed discussion from a micro view
- **Mixability:** cross-correlation effects between multiple datasets
- **Meaning:** data mining led by application scenarios
- **Multidimension:** cross-comparison and fusion among multiple datasets

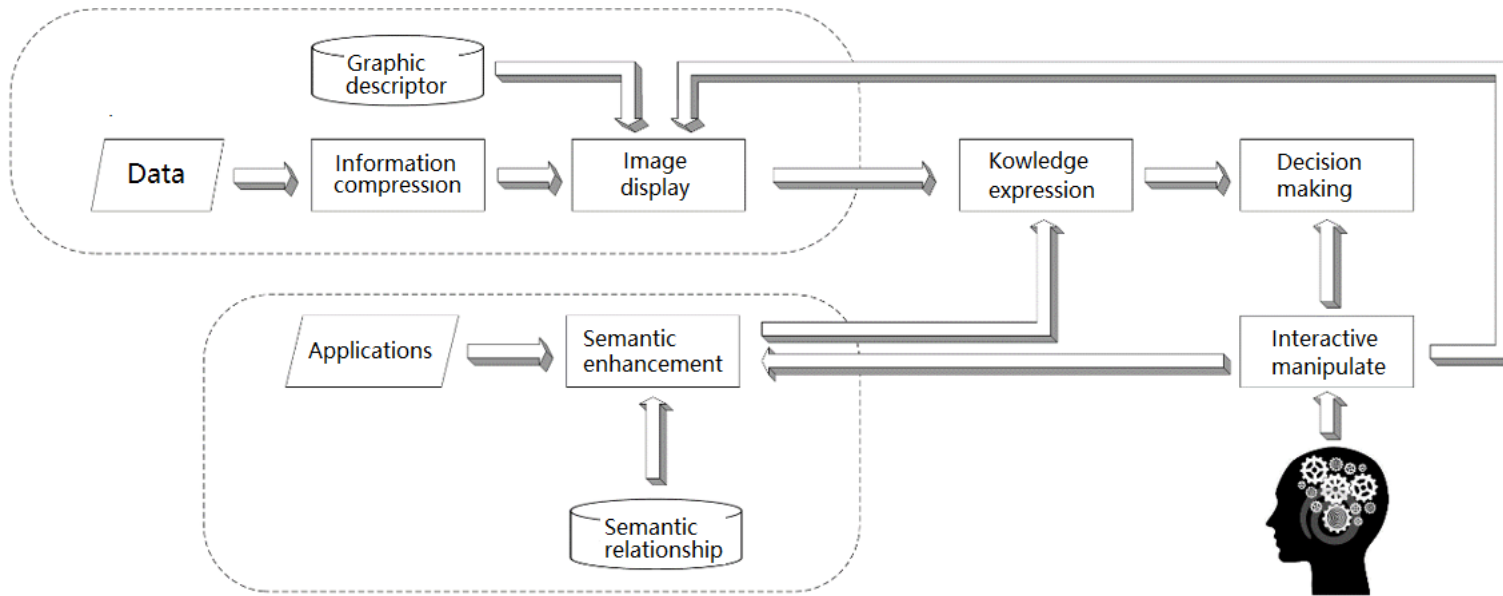
**Sun, X.,** Sun, T. The 4M thinking mode for public management in the big data era: theoretical thoughts and practical exploration[J]. The Journal of Shanghai Administration Institute, 2019, 20(1): 56-65. (in Chinese)

## Approach innovation: Visual urban governance (VUG)

## Human-machine collaboration will become closer in our daily work

With big data, how to explore, understand, and operate the **virtual world**, and then improve the public management ability of the **real world** is a major issue

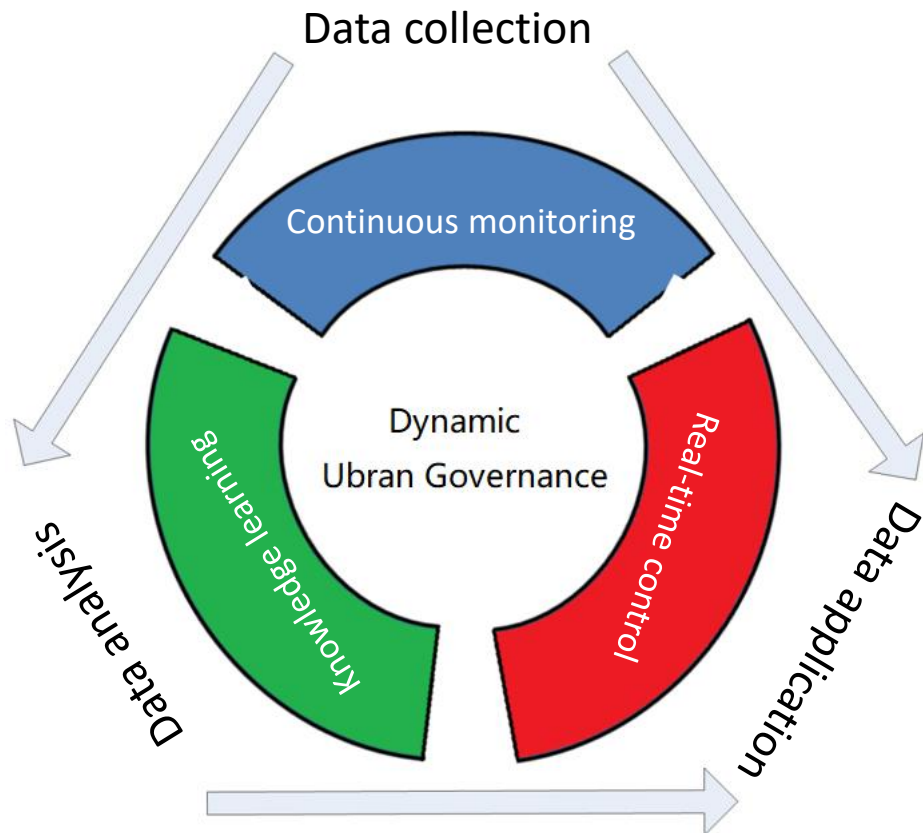
For example: **Visual urban governance based on big data**



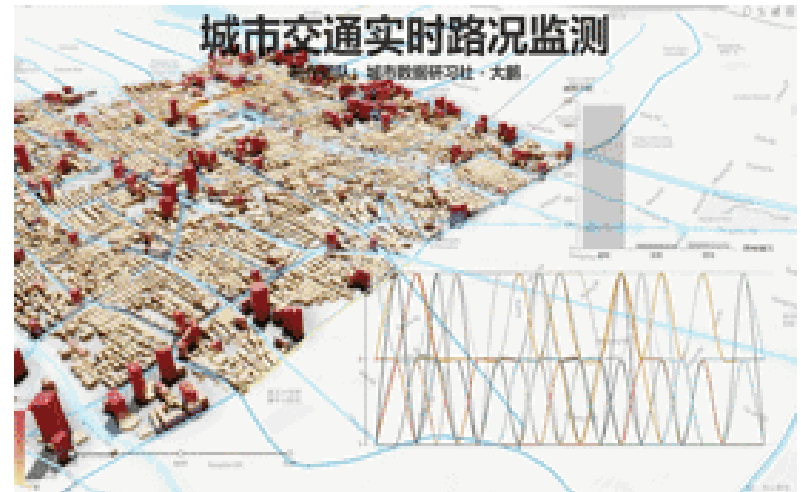
**Sun, X.,** Sun, T. Visual urban governance based on big data: decision supporting model and typical practices[J]. Journal of Public Management, 2018, 15(2): 120-129.

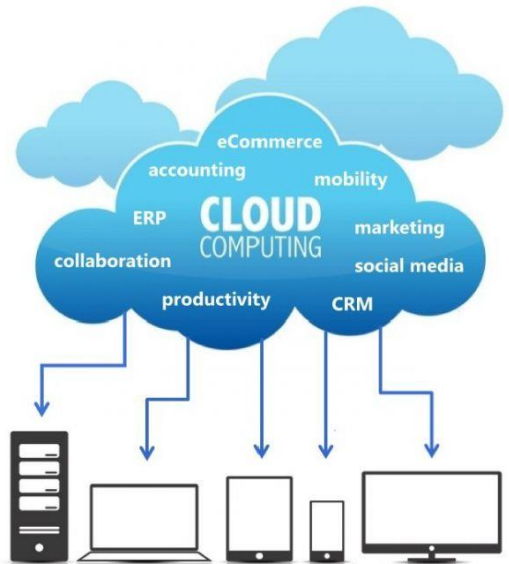


# System innovation: Dynamic urban governance (DUG)



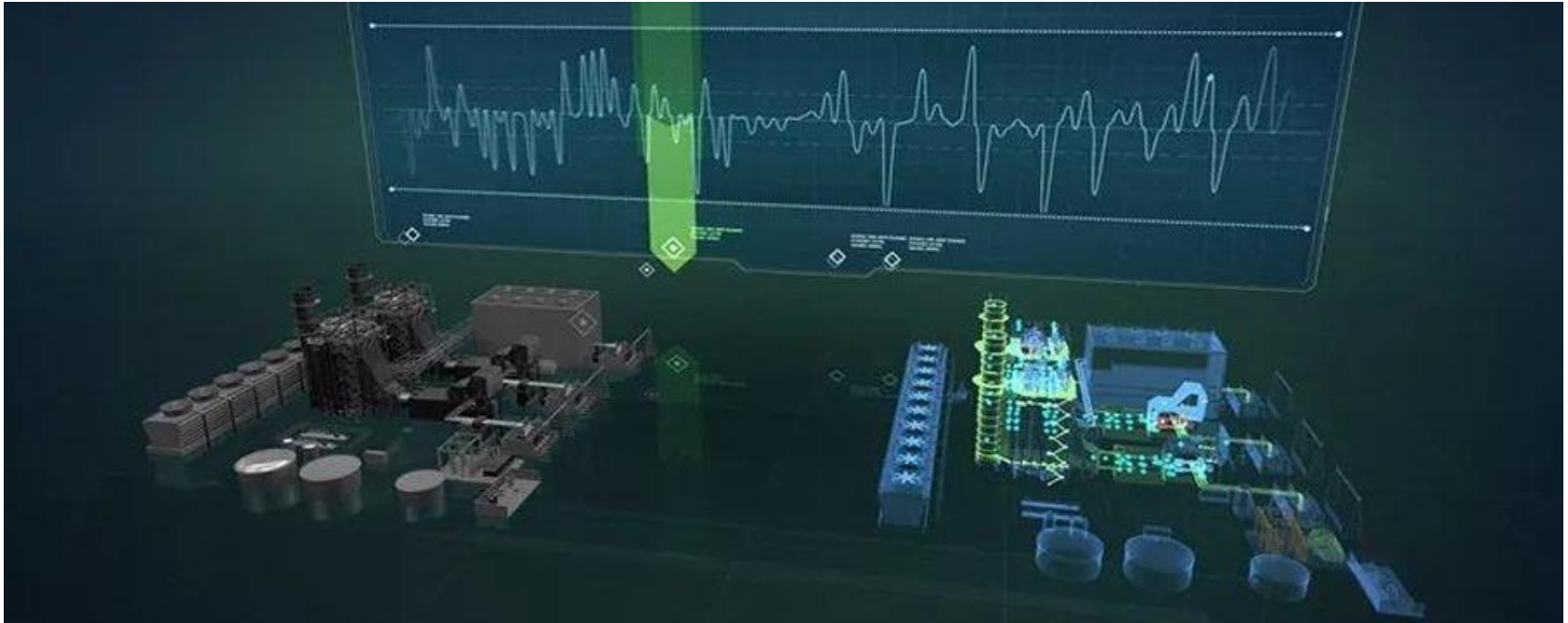
**Sun, X.,** Sun, T. Urban dynamic governance in big data computing environment: conceptual connotation and application framework[J]. E-Government, 2020, (1): 20-28. (in Chinese)





## Technology application and improvement

# Digital twin

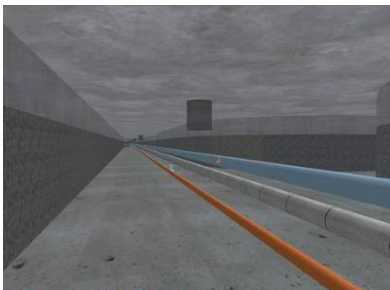
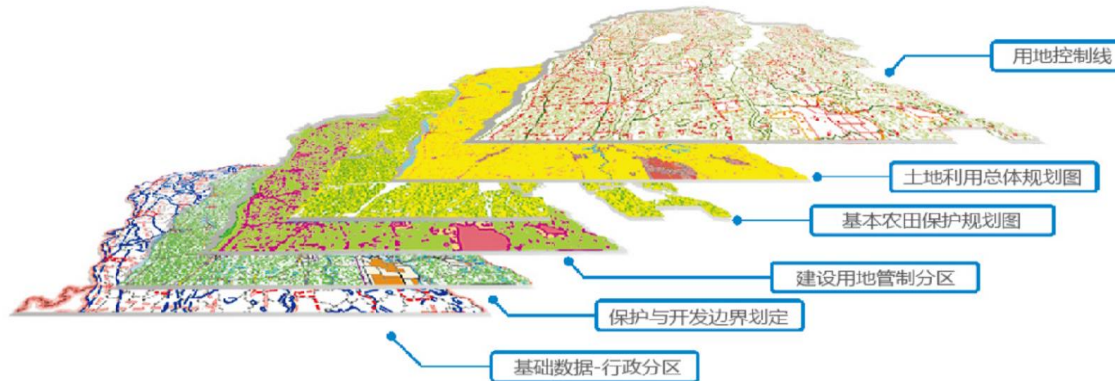
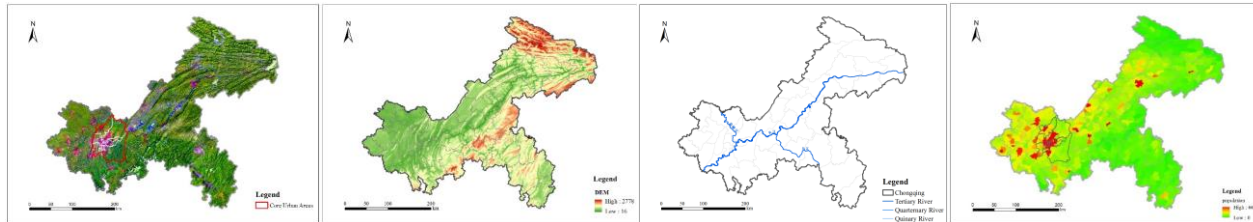


The real world is being **precisely** and **realistically** mapped into the computers

The data-driven “hyper-reality” environment greatly influences the work modes of many industries



# City information model (CIM)



Social economic datasets



Economic data



Population data



City operation data



Industry data



.....



Dynamic operating datasets



Mobile signal data



IoT sensing data



Monitoring data



Traffic data

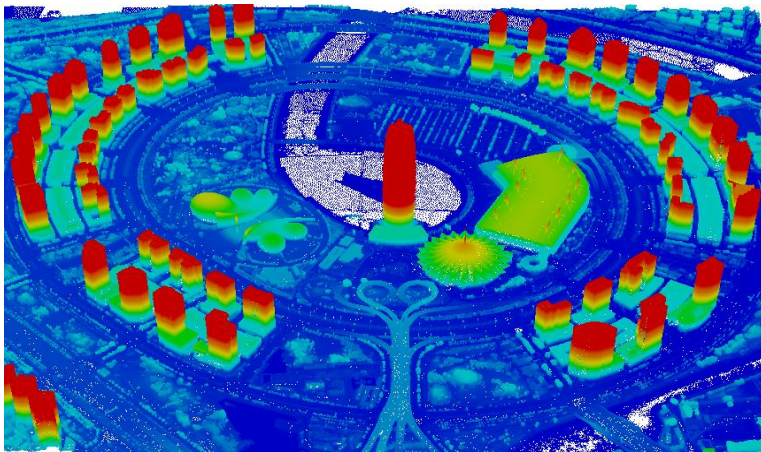
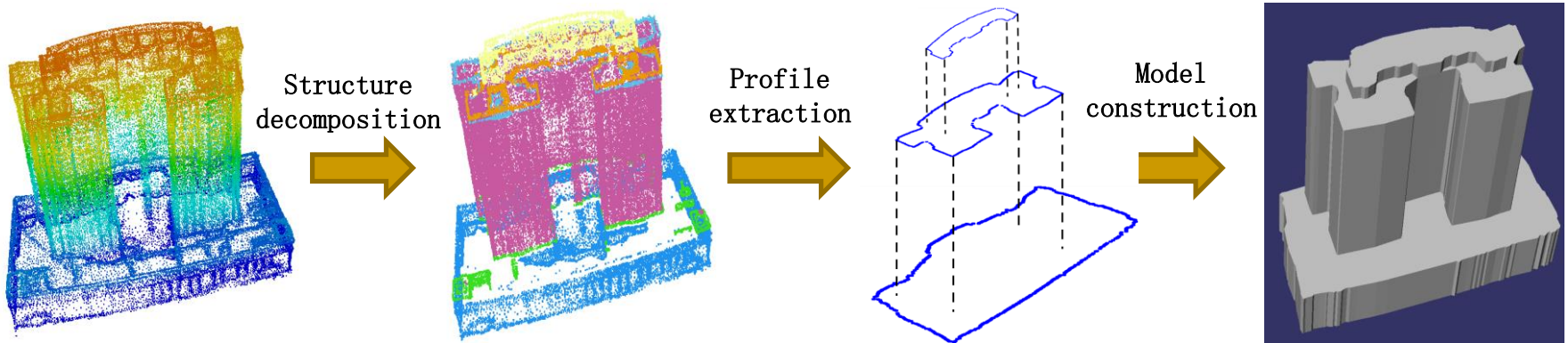


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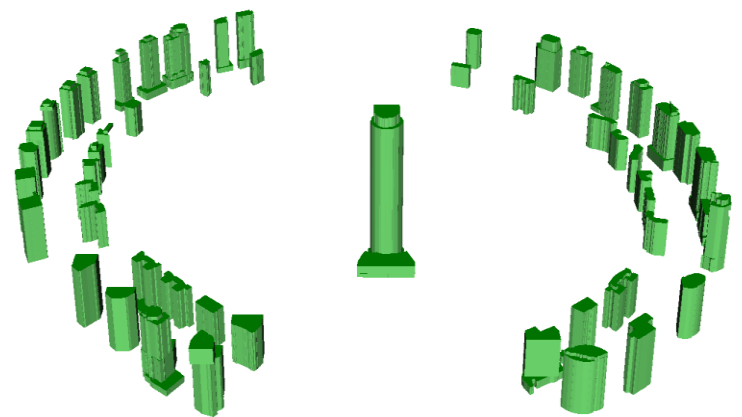
Sun, X., Wei, Y., Tu, W. From CAD Design to Virtual Environment: Underground Pipeline Information System Construction for Smart City[C]. International Conference on Frontier of Energy and Environment Engineering, 2013, 11.



# Geographic space modeling

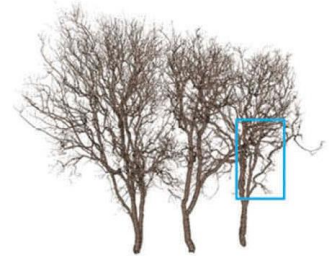
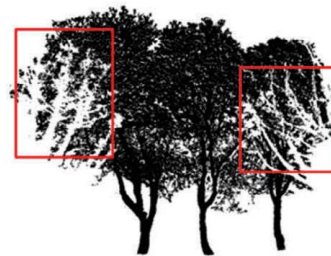
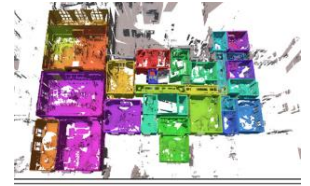
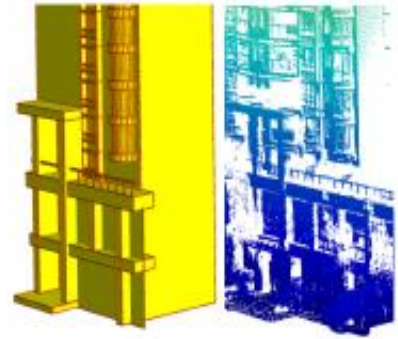


Dense point clouds



3D model construction

Sun, X., Li, Q., Yang, B. Compositional structure recognition of 3D building models through volumetric analysis[J]. IEEE Access, 2018, 6: 33953-33968.

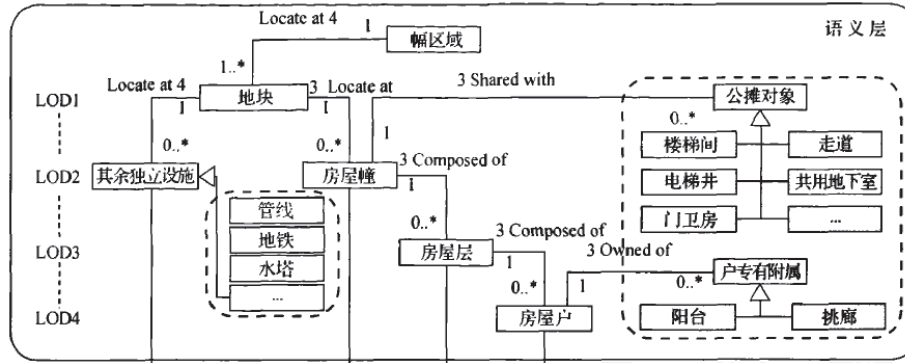


More than 72,000 buildings in Central Tianjin

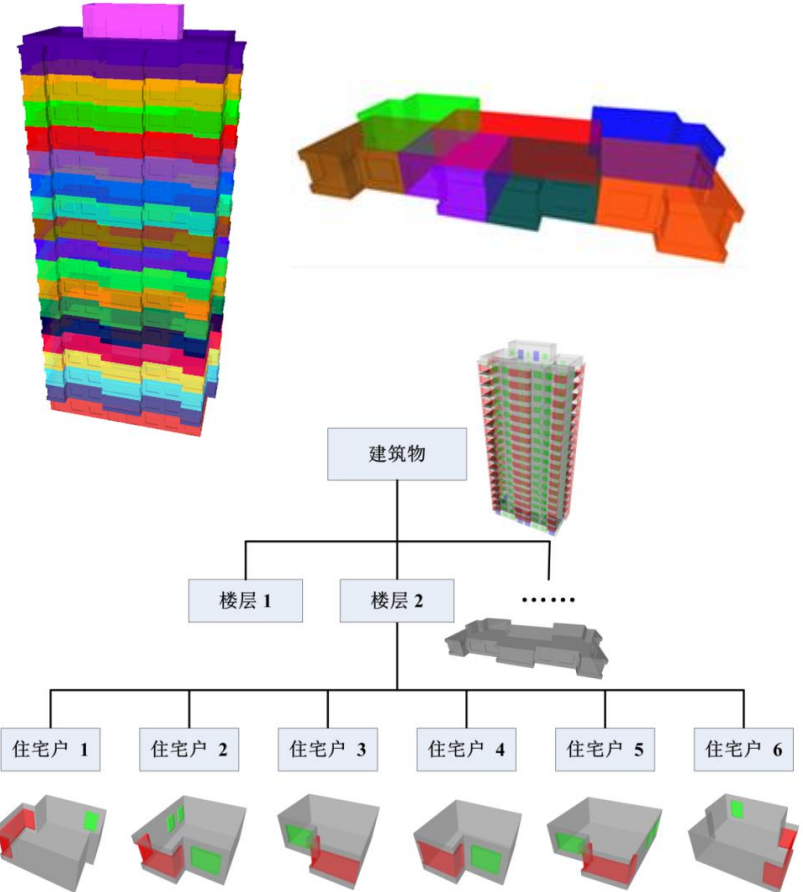
4/10/2023



# Semantic space modeling



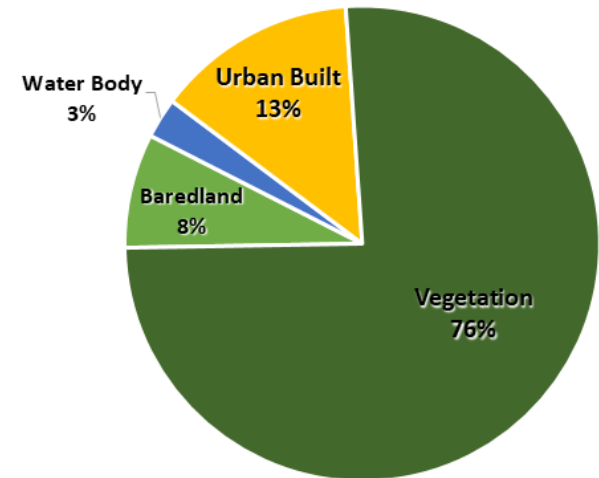
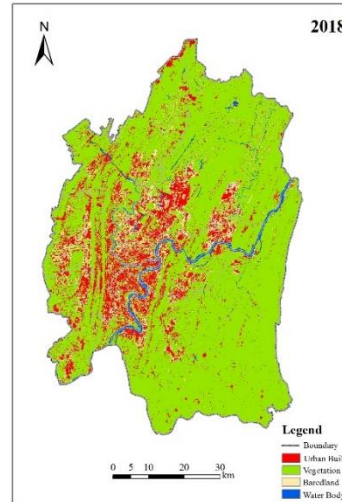
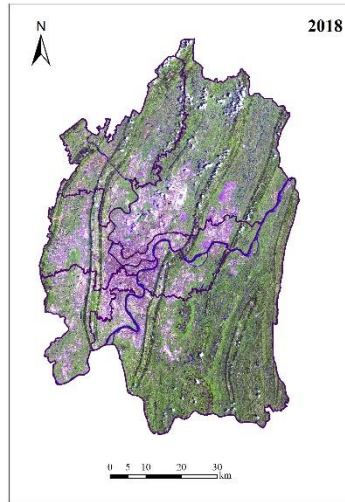
**Sun, X.** Multilevel semantic modelling of urban building space based on the geometric characteristics in 3D environment[J]. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 42(4): 603-607.



**Sun, X.** Semantic 3D Building Model Construction for Smart Urban Management [C]. Proceedings of the 2015 International Conference on Industrial Technology and Management Science, 2015, 11.

# Urban change monitoring: massive parameters

## Traditional work



## New challenges

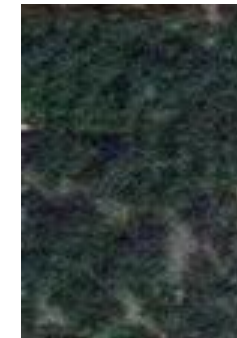


Beijing-2 satellite  
Resolution: 0.8m

Beijing, over 16,000 km<sup>2</sup>  
25 Billion pixels



Heights  
Ages  
Styles  
?



How many trees planted?  
What trees?



How many cars?  
What cars?





## Multiple platforms:

Unmanned aerial vehicle (UAV)

Mobile measuring vehicle

## Multiple views:

Aerial view

Head-up view



*More complete semantic models*

*More detailed parameters*

**“Stereo” semantic description**

**“Massive” parameter calculation**

# Digital management system construction



**Sun, X.** Smart Community construction in China: background, connotation, and practices[J]. Urban Insight, 2020, 70(6): 128-137. (in Chinese)

**Sun, X.** Digital governance innovation driven by technology[A]. Guangming.com (Theoretical Edition), 2021.4.3



Based on the digital models, we can conduct unified and visualized management of various urban information, such as buildings, houses, and residents.

- Comprehensive management
- In-depth analysis
- Planning simulation
- Dynamic Scheduling

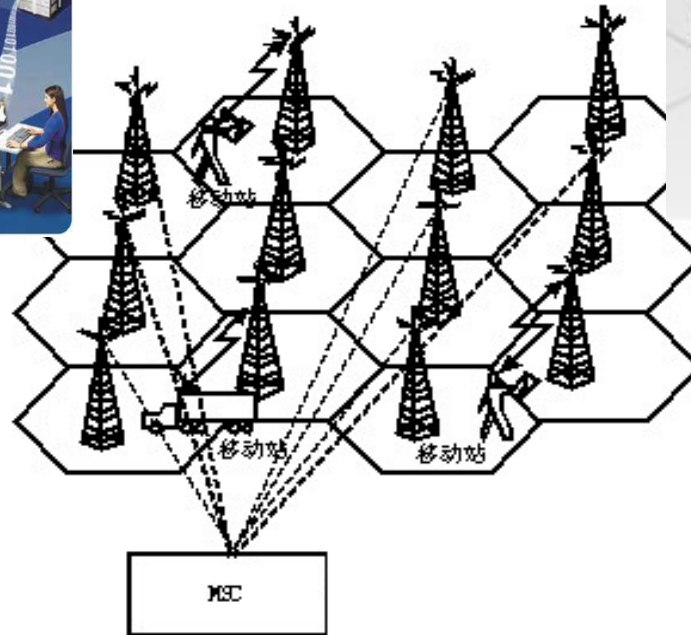


# Information communication technology application



Material flow

Information flow



People flow

**Sun, X.** Promoting data flow in the 5G environment and building a dynamic urban governance system. Guangming.com (Theoretical Edition) [Headline], 2021.1.6.

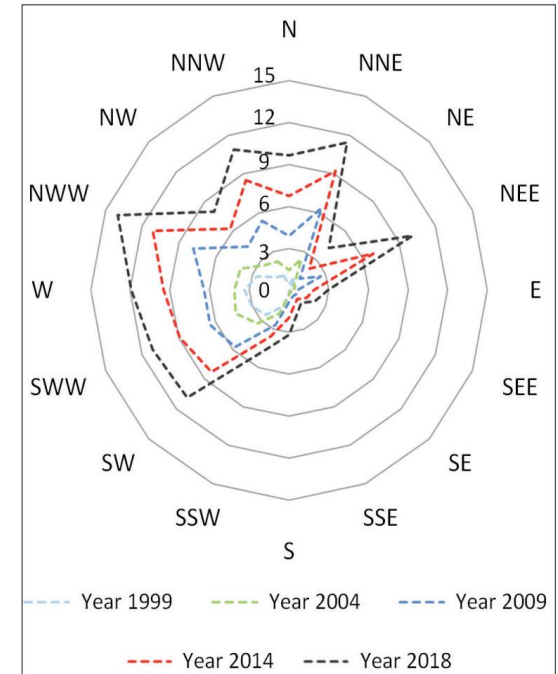
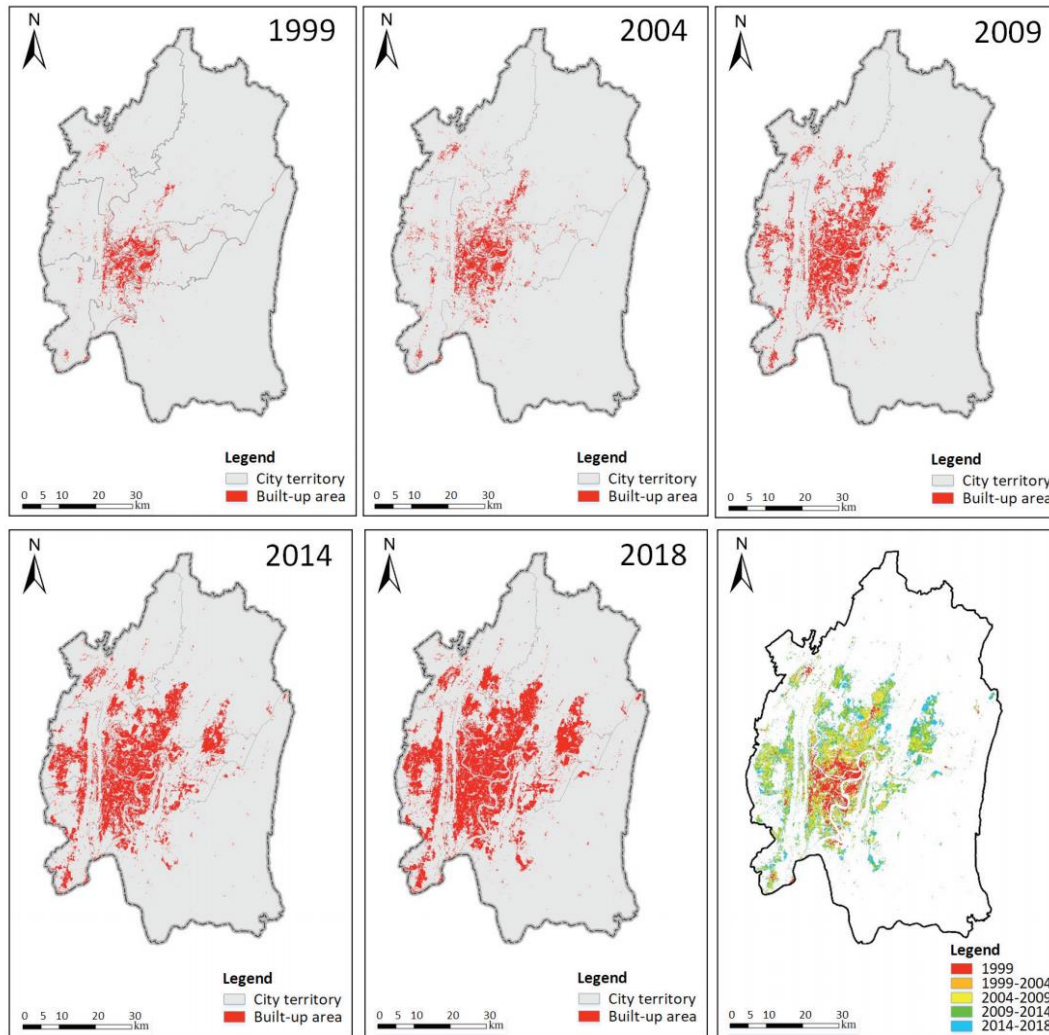
**Sun, X.** Promoting social coordination in epidemic prevention and control through information flow. Guangming.com (Theoretical Edition), 2020.2.17.





## Scientific research and exploration

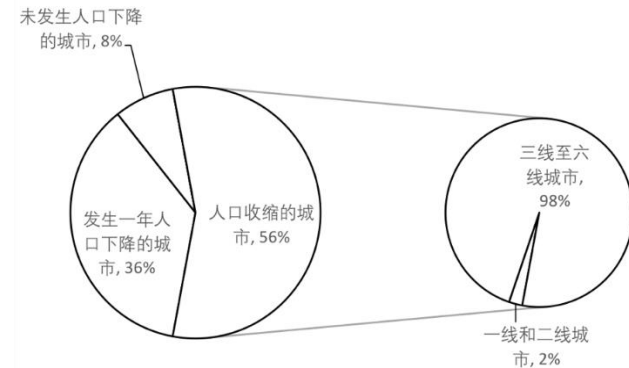
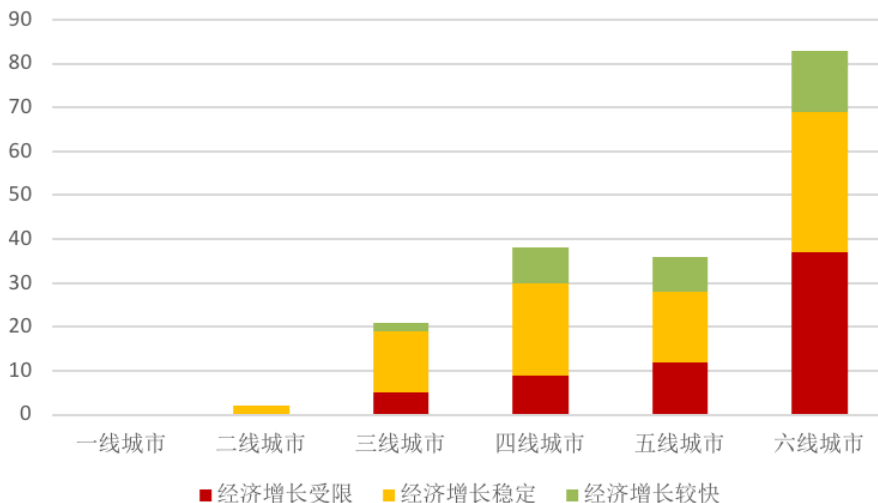
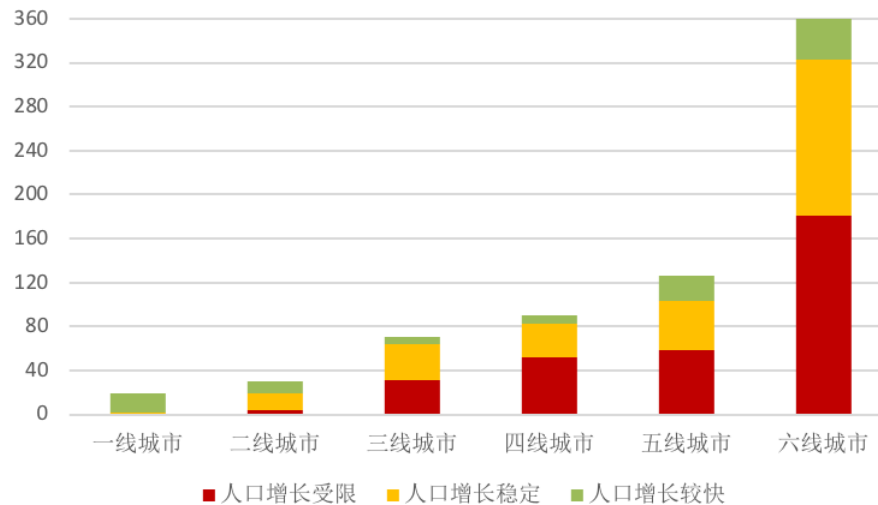
# City organism



**Sun, X., Liu, Y., Sun, T., et al.** Land Cover Changes and Urban Expansion in Chongqing, China: A Study Based on Remote Sensing Images, *Environment and Urbanization Asia*, 2021, 12(1S): 1-20.

## Regional differences in urban development

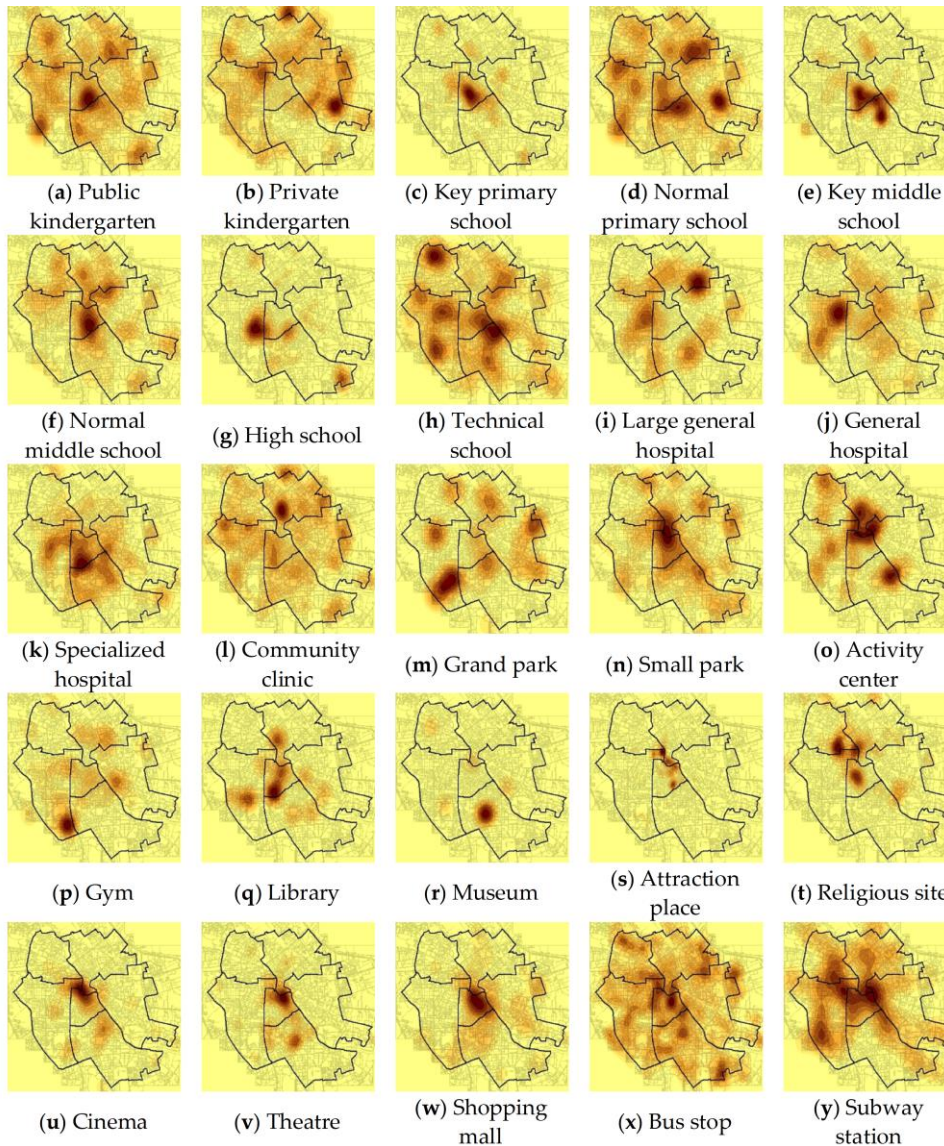
## 695 counties in China



**Sun, X.,** Li, Z., Ji, K., et al. Typology of shrinking cities in China: a discussion based on official statistics from 2000 to 2018, *Environment and Planning A: Economy and Space*, in process.



# Regional differences in living environment



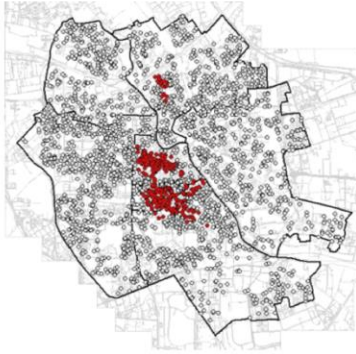
## A city is a giant complex system

Based on the datasets of education, medical care, leisure, entertainment, culture, transportation and other aspects of social infrastructures, the living environment of urban communities was interpreted and understood.

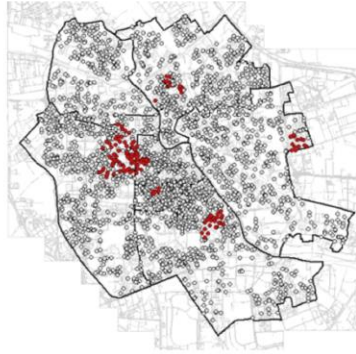
$$Indx(O_{n,i}) = \sum_j w_{i,j} a(t_{n,i,j}),$$

$Indx(O_{n,i})$  is the cumulative accessibility

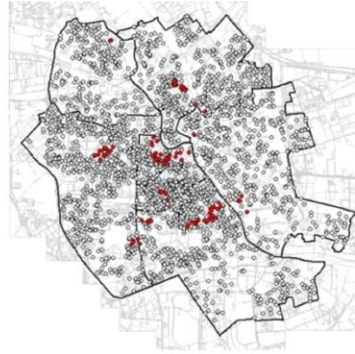
**Sun, X.,** Wang, W., Sun, T., et al. Understanding the Living Conditions of Chinese Urban Neighborhoods through Social Infrastructure Configurations: the Case Study of Tianjin, Sustainability, 2018, 10(9), 3243.



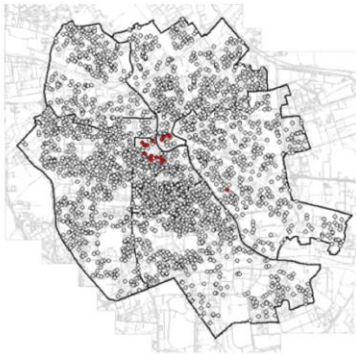
(a) Neighborhoods with advantages in education



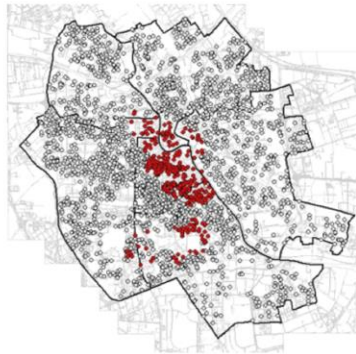
(b) Neighborhoods with advantages in healthcare



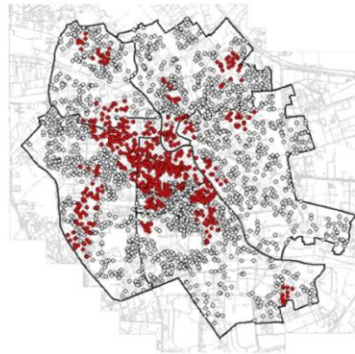
(c) Neighborhoods with advantages in leisure



(d) Neighborhoods with advantages in culture



(e) Neighborhoods with advantages in entertainment

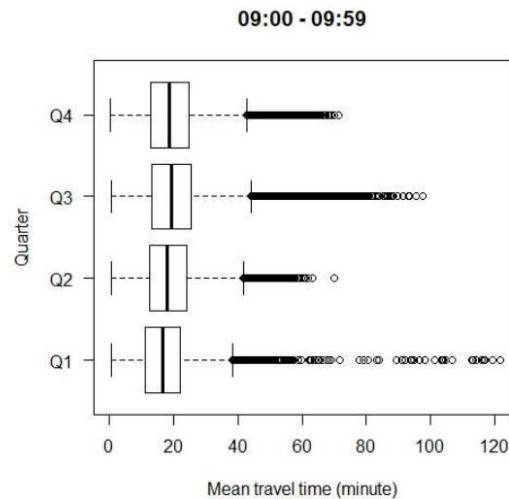
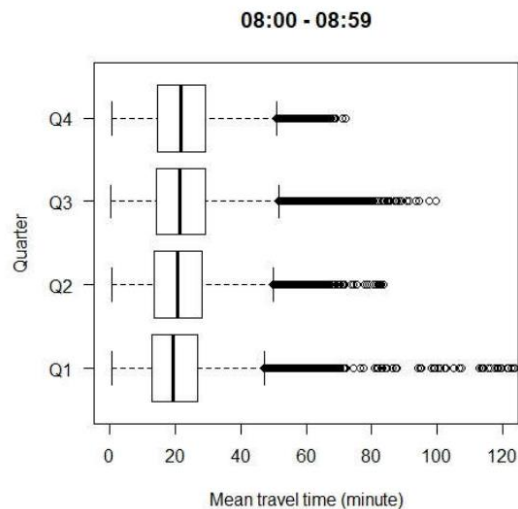
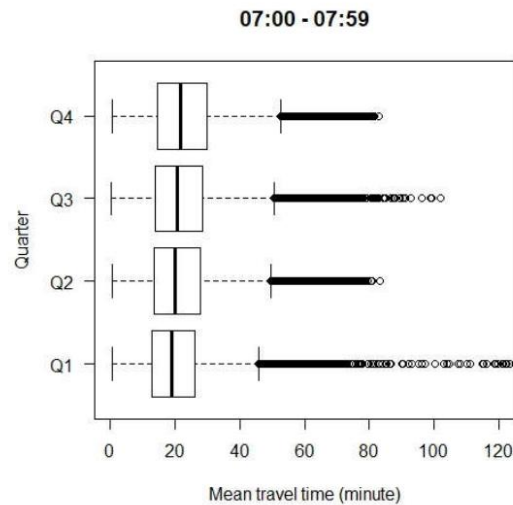
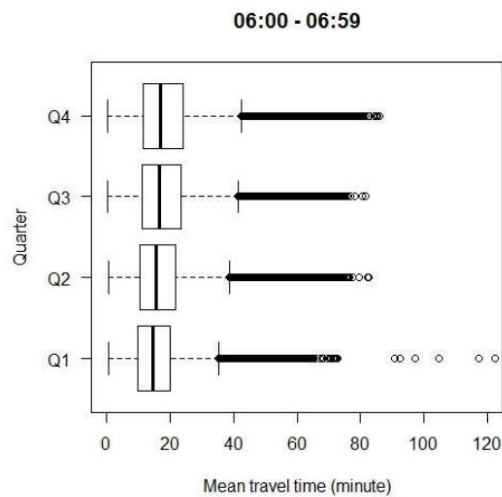


(f) Neighborhoods with advantages in transportation

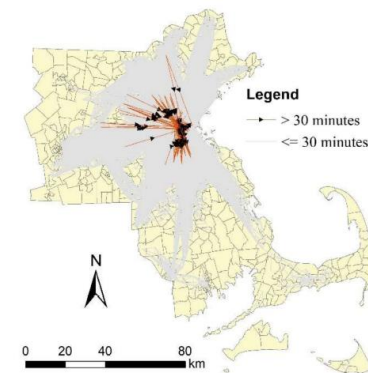
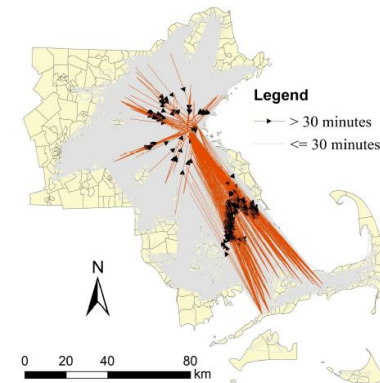
## Judging from the spatial accessibility:

- No community has good living environment in all aspects
- Communities with different advantageous conditions show different distribution patterns
- Except from healthcare, communities located in central urban areas tend to have good living environment in almost all aspects
- 1.7% of communities do not have any advantage in any aspect of living environment

# Seasonal differences in traffic trips



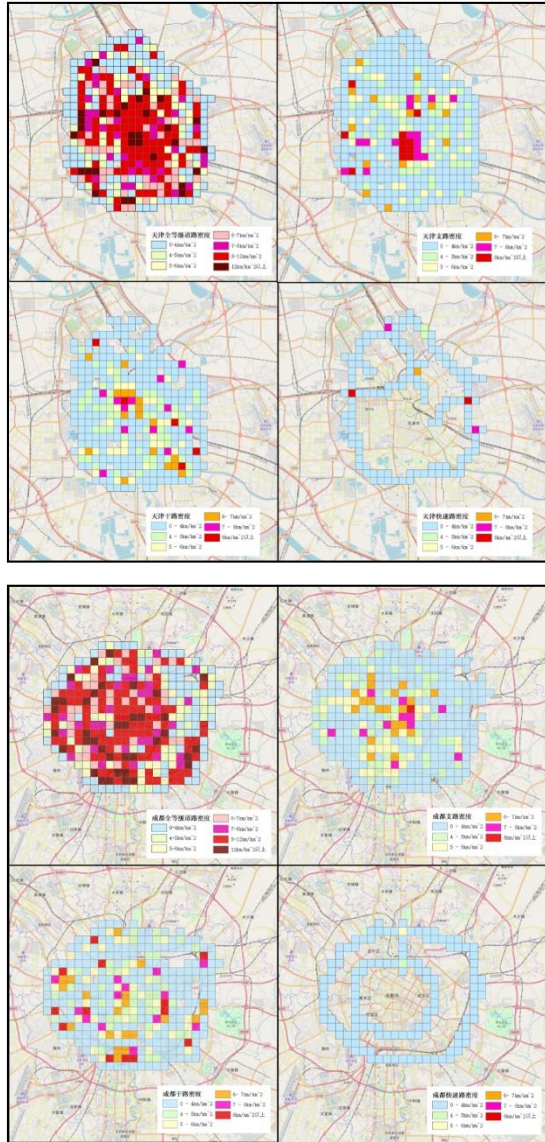
## Boston



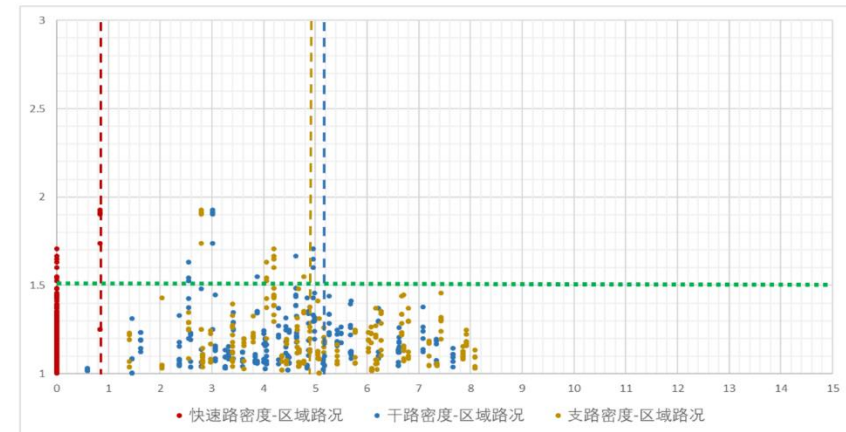
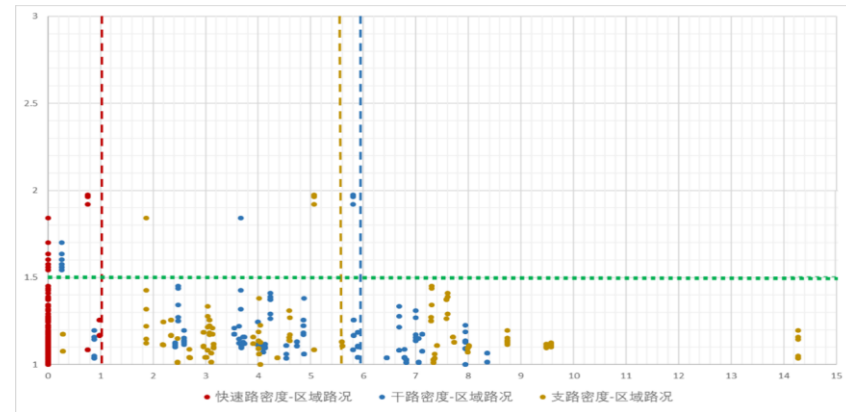
Sun Y., Ren Y., **Sun X.\*** Uber Movement Data: A Proxy for Average One-way Commuting Times by Car[J]. International Journal of Geo-Information, 2020, 9(3):184.



# Urban structure and city operation



## Studies on the central regions of **Tianjin** and **Chengdu**



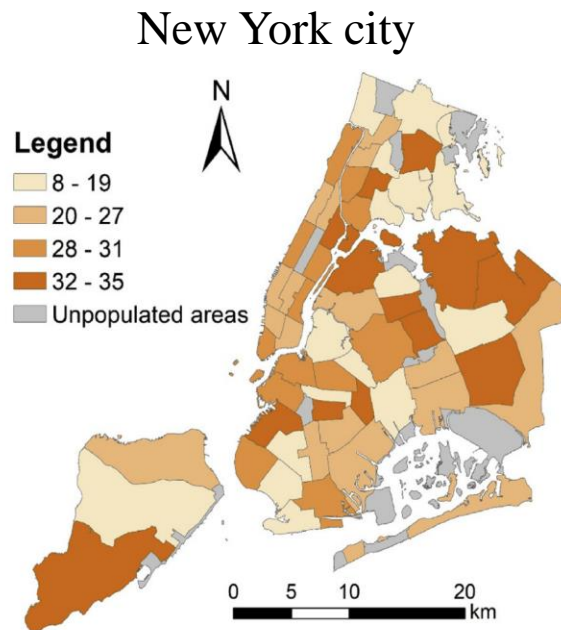
Sun, X., Yu, K., Wang, Y. The Impact of Road Network Density on Urban Traffic Congestion: Case Studies of Tianjin and Chengdu[J]. Transport and research part D: transport and environment, in process.

# Behaviour and physical health

Independent variables (predictors) considered in this study.

Variables	Subcategories	Full names	Explanations	Years
Socio-economic status	NWP	Non-white population	Percent of non-white individuals	2013
	AAG1	Adults of age group 1	Percent of adults aged 18 to 24 in the population	2013
	AAG2	Adults of age group 2	Percent of adults aged 25 to 44 in the population	2013
	AAG3	Adults of age group 3	Percent of adults aged 45 to 64 in the population	2013
	AAG4	Adults of age group 4	Percent of adults aged 65 and older in the population	2013
	POV	Poverty	Percent of individuals living below the federal poverty level	2011–2013
	UEP	Unemployment	Percent of the civilian labour force aged 16 and older who are unemployed	2011–2013
Behavioural factors	SDC	Sugary drinks consumption	Percent of adults who report drinking one or more 12 ounce sugar-sweetened beverage per day	2011–2013
	FVC	Fruits and vegetable consumption	Percent of adults who report eating at least one serving of fruits or vegetables in the last day	2011–2013
	PAP	Physical activity prevalence	Percent of adults who report getting any physical activity in the last 30 days	2011–2013
Built environment characteristics	SA	Supermarket accessibility	Supermarket square footage per 100 residents	2014
	LUX	Land use mix	Entropy-based land use mix	2017

NWP, non-white population; FVC, fruits and vegetable consumption; PAP, physical activity prevalence; LUX, land use mix; SA, supermarket accessibility.



Compared with **socio-economic** and **built environment** factors, **behavioural factors** make statistically significant contributions to spatial disparities in the **prevalence of adult obesity (POAO)**.

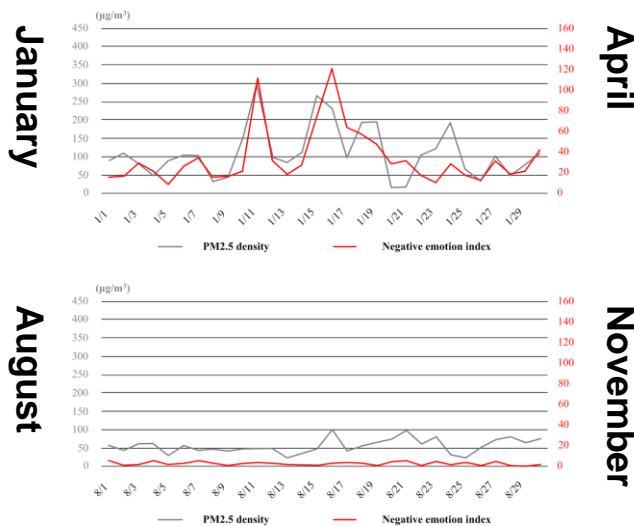
**Sugary drinks consumption** and **fruits and vegetable consumption** can explain more than 70% of the variance of POAO.

Sun, Y., Wang, S., **Sun, X.** Estimating neighbourhood-level prevalence of adult obesity by socio-economic, behavioural and built environment factors in New York City[J]. Public Health, 2020, 186:57-62.

# Environment and mental health



Analyze the relationship between **air quality** and **public sentiment**, with micro-blog big data and historical records of weather conditions



**Sun, X.,** Yang, W., Sun, T., et al. Negative emotion under haze: an investigation based on the microblog and weather records of Tianjin, China, International Journal of Environmental Research and Public Health, 2019, 16(1), 86.





浅灰的金子

这一周，从周日晚上到今天下班为止都特别疲惫，终于所有的工作都结束了。不用加班了。本来累到极致终于可以休息是件很美妙的事儿。现在却感觉心情很糟糕。满满的负能量好像跟窗外的雾霾交织在一起。哎...

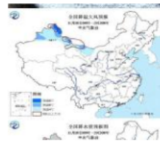
2014年11月22日 00:04 来自 iPhone客户端

- **A certain correlation** between haze and public negative sentiment, but the strength of the correlation **varies under different conditions**
- **Air pollution degree** and **weather change** are important factors affecting the emotional effect of haze
- **Different seasons** of the year have different patterns of impact of haze



Blackieieieie\_

北京雾霾何时了？看到：雾霾，二字就烦恼！//【强冷空气今袭新疆 京津冀雾霾再起】[强冷空气今袭新疆 京津冀雾霾再起](#) (分享自 @今日头条)



2014年11月28日 12:08 来自 今日头条

According to the research results, the haze governance could be improved from several aspects:

- 1) Establish a long-term public sentiment **monitoring system** based on social media;
- 2) Considering the affecting factors and seasonal patterns of haze impact, take **adaptive measures** under different situation;
- 3) Based on **social psychology** theory, try to relieve the negative emotions of the public under haze.



小子前途不可限量

这该死的雾霾只能让人躲在屋子里清新、



2014年11月29日 13:56 来自 iPhone 5s



亦农

尼玛，这个雾霾笼罩的世界，无处可逃了。



2014年11月29日 10:01 来自 三星android智能手机



故傳荏延續

可怕的雾霾 [天津·天津公安警官职业学院](#)

2014年12月28日 09:25 来自 iPhone 6 Plus

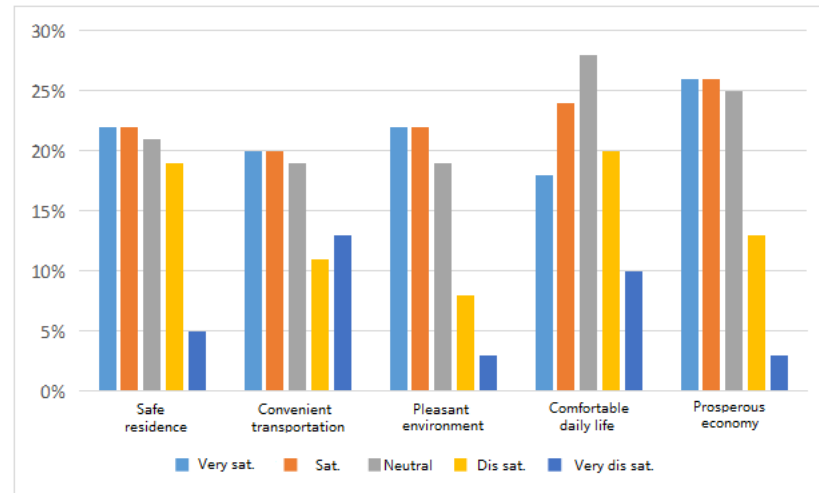
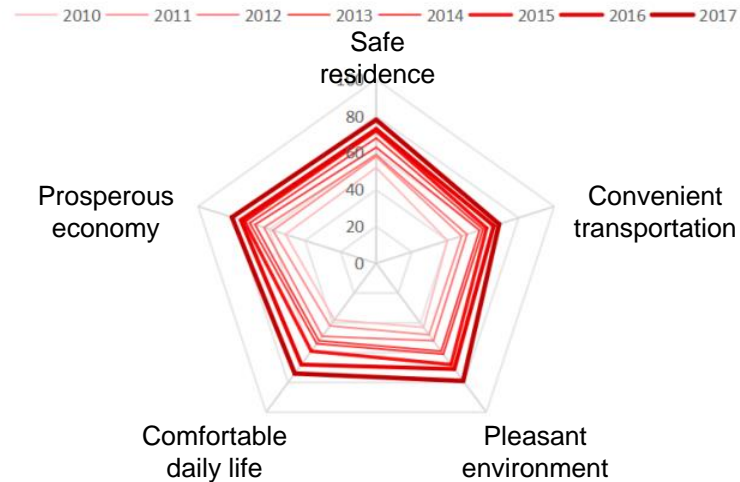
收藏

转发

评论



# Achievements and demands



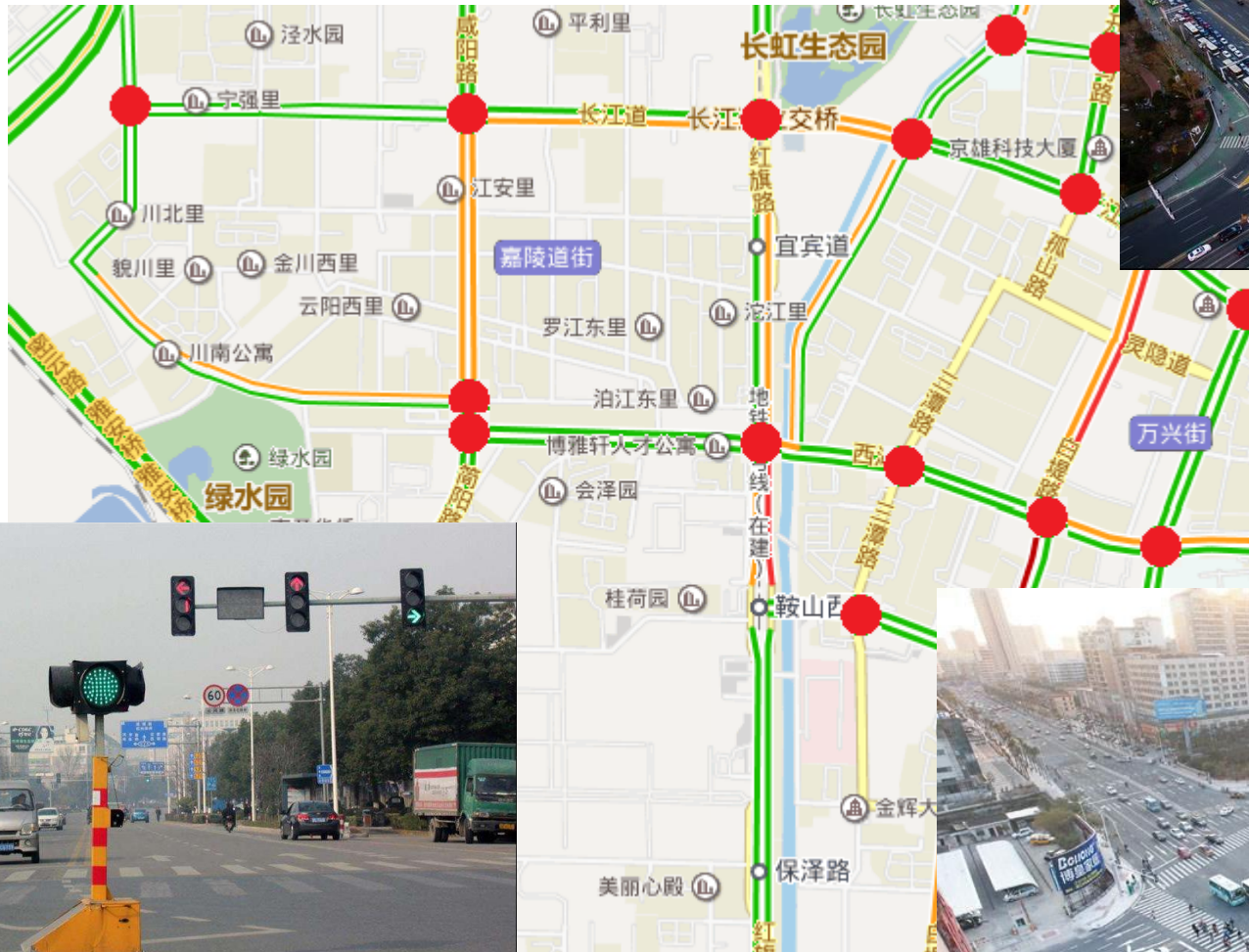
**Sun, X.,** Li, X., Hou, J. Achievements and demands of ecological city construction in China: the case study of Sino-Singapore Eco-city, Habitat International, in process.



## Computational modeling and optimization



# Urban modeling: city operation (complex relationships)





Central area of Tianjin (6 districts)

More than 37,000 signal lights

How to **control the signal lights**, to optimize the operating efficiency of the entire road system?

## NP-hard problem

*Point control*

*Line control*

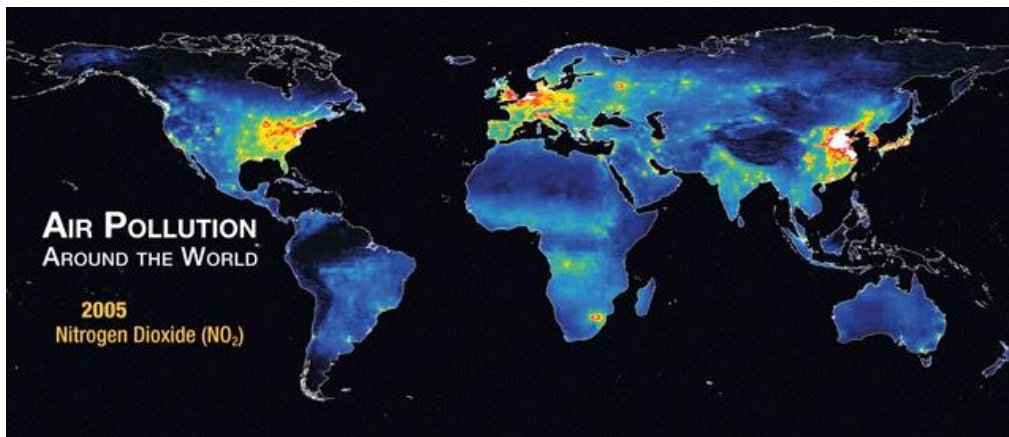
*Area control*

**Overall  
optimization**

**?**

# Urban modeling: environment changes (cross interactions)

- **Existing research:** static, isolated studies of environmental elements
- **Environment flow:** dynamic, universal connected view
  - **Material flows**, including water resources, energy, traffic flow, green products, greenhouse gases, waste, etc.
  - **Non-material flows**, such as the information, dialogues, and movements produced by humans around material flows.





# Urban modeling: public health (Multiple views)

## Physical health:

- medical insurance information
- health check information
- internet consumption information
- living environment information
- daily work status
- .....

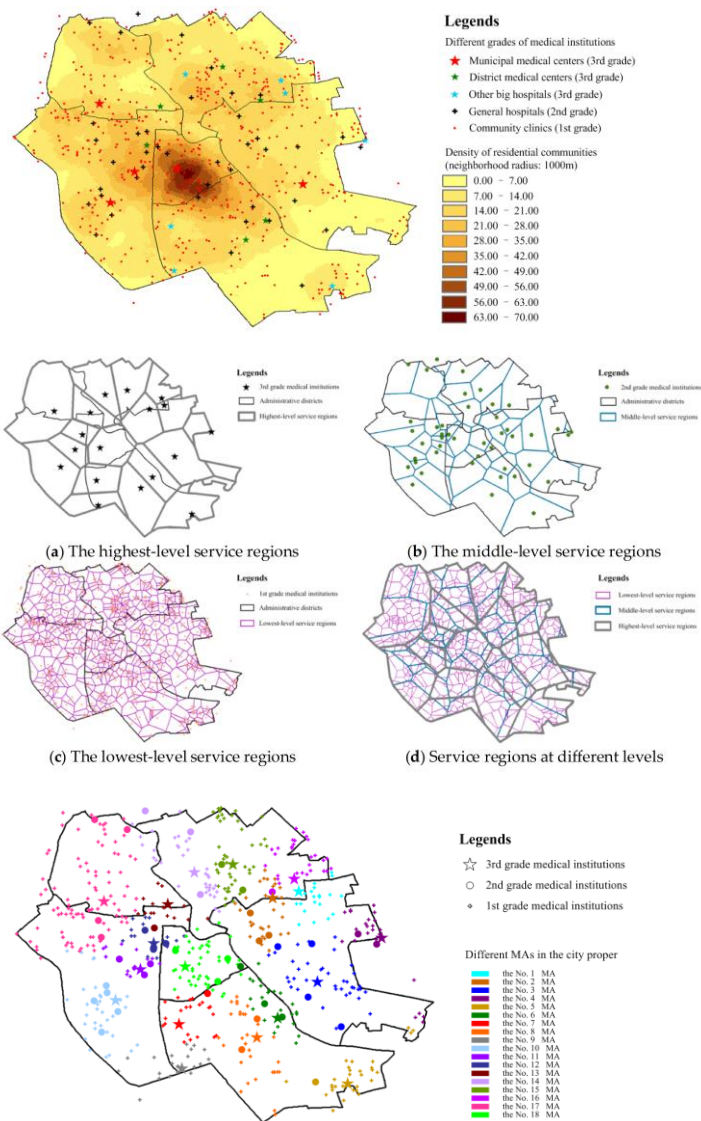


## Mental health:

- social interaction information
- social media information
- web search information
- internet reading information
- .....



# Example: public service optimization



How to organize and manage **medical care resources** within the city has always been a hot issue of public health management.

Based on:

- ① **POI** (point of interest) map of healthcare infrastructures
- ② Medical **public service information** in “Directory of Medical Institutions of Human Resources and Social Security Bureau”

From the spatial perspective, we discuss the construction of **medical alliances** within Tianjin city, to achieve **efficient use of limited resources** among hierarchical healthcare infrastructures.

Based on the **model** and **dynamic big data**, Smart Medicine system could be established.

**Sun, X.,** Sun, T., Jin, Y., et al. Spatial organization of hierarchical medical services within the city proper of Tianjin, China: towards efficient medical alliances, sustainability, 2019, 11(1), 229.

# Potential data resources

## Vehicle

出租、互联网出行、两客一危、物流车、私家车、保险

车辆轨迹		1000亿+公里		车辆画像		车主数据		车辆传感器	
车辆轨迹	位置	车辆画像	厂牌型号	车主数据	身份信息	车辆传感器	GPS	摄像头	
	时间		座位吨位		出行区域		雨刷	急刹	
	速度		载重量		出行时间		头灯	点火	
	方向		购置价		驾驶行为		雾灯	应急灯	
	精度		使用年限		驾驶习惯		ABS	ESC	

## Road

四维图新

标准地图	14年, 635万km	ADAS地图	50+城市	高精度地图	6万+km
路网形状		路网形状		车道级道路属性	
道路属性		道路属性		道路附属对象	
其它属性		其它属性			
动态数据					340+城
交通路况	交通事件	交通限行	交通天气	停车场	充电桩

## Human

保险、电信运营商、互联网应用

个人画像		
基本属性	行为特征	心理特征
购买能力	兴趣爱好	社交网络
群体画像		
人口属性	职业属性	消费属性
商业属性	出行属性	企业属性

## Environment

国家气象局、公众环境研究中心

天气数据	污染数据
温度	水质
风力	空气
能见度	废水源
降水量	废气源

## Urban infrastructure

四维图新、航天集团

POI	5000万+	背景	行政区划	现场资料
生活类		绿地	省级行政区划	2亿
行车类		水系	市级行政区划	沿路照片
商业类		工业、交通、商业、住宅、文、教、卫、公园	区县行政区划	2000万+ 360度全景照片
出行类		地表植被、土壤、湖泊、沼泽湿地、建筑物	卫星影像	10万+公里 点云
室内图		山体阴影图	0.8m卫片	全国融合
			2m卫片	
			16m卫片	



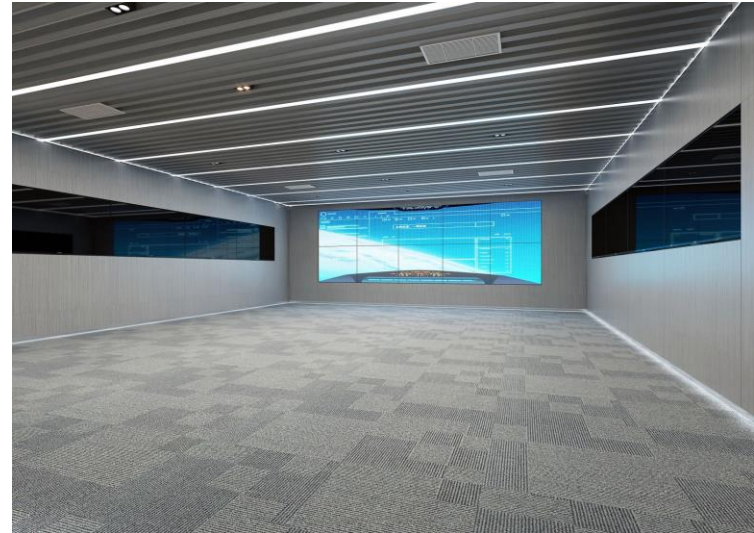
# Industry-university-research cooperation

- **State Key Laboratory of Surveying, Mapping and Remote Sensing, Wuhan University**
  - Luojia-1 satellite (nighttime light remote sensing)
  - Surveying and Mapping UAV
  - Mobile measuring vehicle
- **NavInfo Digital Map Company**
  - Full-featured city map data
  - Real-time traffic data
  - Traffic travel data (bus, taxi)
- **Municipal Planning and Resources Bureau, Sino-Singapore Eco-city Management Committee, Municipal Construction Committee, Municipal Medical Insurance Bureau, Civil Affairs Bureau, Municipal Rail Transit Group...**

# Digital City Governance & Urban Planning and Design



# Computational Social Science (Provincial Lab.)





# Research projects

- 2021, **National Natural Science Foundation of China**, Demand-oriented Urban Community Life Service Circle Construction Evaluation and Optimum Development Strategy Research (72074127), PI
- 2020, **Tianjin Philosophy and Social Science Research Project**, Tianjin Smart City Construction and Application Development (TJGL19-005), PI
- 2019, **Fundamental Research Funds for the Central Universities**, Semantic Modeling of Urban Space and Computation Applications (63192205), PI
- 2016, **National Natural Science Foundation of China**, Structure-based multi-level semantic modeling of 3D urban building space (41501427), PI
- 2015, **Asia Research Center Funded Project**, Urban Governance Methods Based on Big Data (AS1522), PI
- 2014, **Shenzhen Key Laboratory of Spatial Smart Sensing and Services Open Fund Project**, Multi-level Structure Recognition of 3D Urban Complex Models, PI
- 2014, **Fundamental Research Funds for the Central Universities**, the Basic Theories of Digital Urban Management (NKZXB1483), PI

# Thank for your attention !

Welcome communication  
and cooperation

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