2024 THNS TRANSFORMING TRANSPORT
Transport à Haut Niveau Service

Session 9: Urban design and sustainable

Cluster analysis of underground space in the core area of new districts from the perspective of urban morphology

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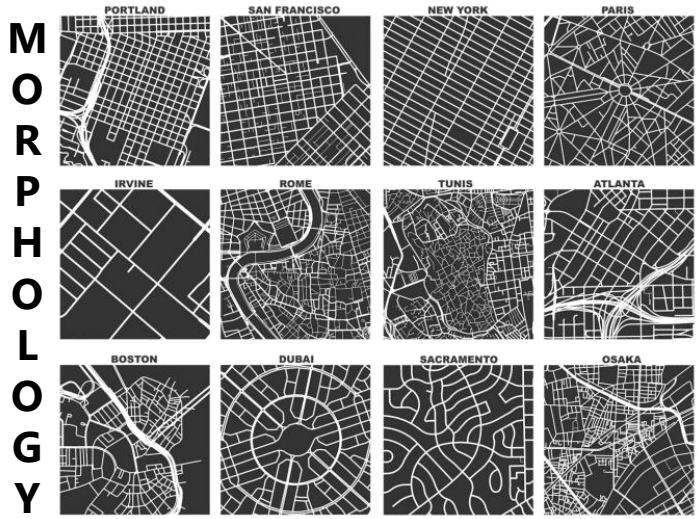
Background



GeoShanghai 2024 – Volume 4 IOP Publishing
IOP Conf. Series: Earth and Environmental Science 1333 (2024) 012006 doi:10.1088/1755-1315/1333/1/012006

Cluster analysis of underground space in the core area of new districts from the perspective of urban morphology

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Abstract. Extensive underground space development worldwide has significantly contributed to the sustainability of social, ecological, and economic growth. In view of the tendency towards haphazard urban sprawling during the development of new areas in China, underground spaces have been increasingly utilized to create sustainable and resilient urban built environments. However, insufficient attention has been paid to their morphological characteristics, resulting in a lack of sustainable and resilient underground space morphological planning and design techniques. To bridge this gap, we established a computational morphology indicator system pertaining to underground spaces, considering land use, spatial distribution, and street networks. We selected 20 underground spaces in well-developed core areas of new districts in China. Hierarchical cluster analysis was adopted to investigate the morphological features of underground spaces. Additionally, the typology of underground space morphology and the corresponding characteristics were systematically summarized to facilitate decision-making for different patterns of underground space planning.

1. Introduction

Rapid urbanization in China has resulted in the drastic expansion of new areas over the past decades. To enhance the sustainability and resilience of urban environments, urban underground spaces (UUSs) are being increasingly utilized to optimize urban land use, transport, and economy [1]. Nevertheless, sufficient attention has not been paid to UUS morphology, a crucial aspect of urbanism. This has resulted in a lack of awareness regarding pluralism and interaction of various elements of UUS, consequently leading to a dearth of planning techniques pertaining to underground space morphology.

- **Urban rail transit** frequently serves as an effective means of **developing new districts**.
- In this context, **how to develop underground space in new districts by the construction of metro stations** becomes an important topic, as it determines the **sustainability of social, ecological and economic growth** to some extent.
- Insufficient attention has been paid to the **morphological characteristics**, resulting in a lack of **sustainable underground space morphology planning and design techniques**.

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Urban morphology indicators

Analyze the features of underground space in new areas, and establish the morphology indicator system

	Calculation
Land Use	
1 Land use density (DEN)	The ratio of underground area to site area
2 Land use diversity (DIV)	The discrepancy between underground SHDI and ground SHDI
Spatial Distribution	
3 Areas of high development intensity (AHDI)	Identified by POIs of storey and floor area
4 Areas of high vitality (AHV)	Identified by POIs of small catering facilities
5 Areas surrounding metro stations (ASMS)	Number of POIs within 500 meters of the metro station domain
Street Network	
6 Synergy (SYN)	Synergy of the underground space network calculated by DepthmapX

Study cases

Well-developed underground space in the core areas of new districts in China are selected.

Land Use

1 Land use density (DEN)

2 Land use diversity (DIV)

Spatial Distribution

3 Areas of high development intensity (AHDI)

4 Areas of high vitality (AHV)

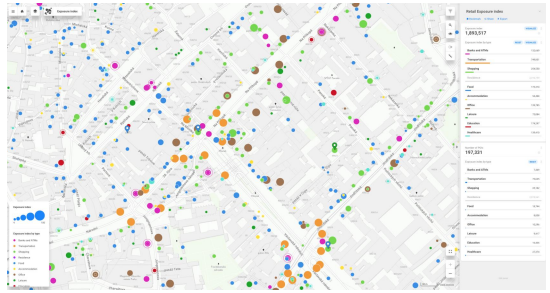
5 Areas surrounding metro stations (ASMS)

Street Network

6 Synergy (SYN)

Data sources

To calculate these indicators, we collected data on…



Point of Interest (POI)

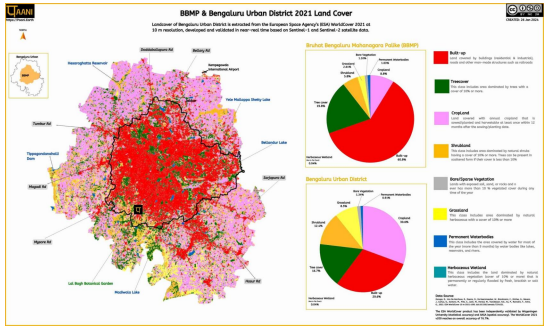
Be obtained from the Baidu Map Open Interface

- Identify UPOIs by keywords detection of address
- Investigate UUS distribution by kernel density and proximity analysis

Building Footprint and Street Network

Be downloaded and processed through OSMnx

- Building footprint: identify areas of high development intensity
- Street network : analyze synergy in DepthmapX



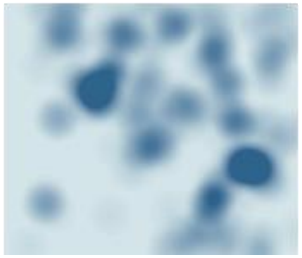
Land Use

Be sourced from the official Bureau of Natural Resources for each city

- Analyze datasets related to land boundaries, scope, quantity, and usage of study areas
- Test the effectiveness of the POI data

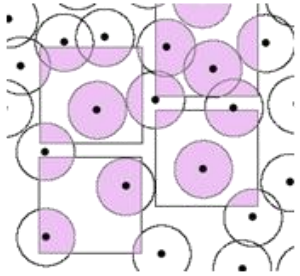
Methods of Analysis

In processing these data, we employed a range of techniques…



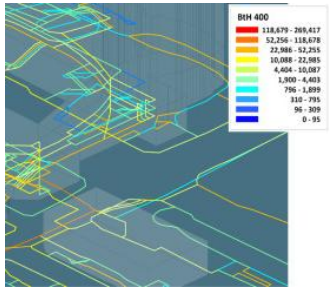
Kernel Density Analysis

- Identify AHDV by POIs of building footprint
- Identify AHV by POIs of small catering facilities



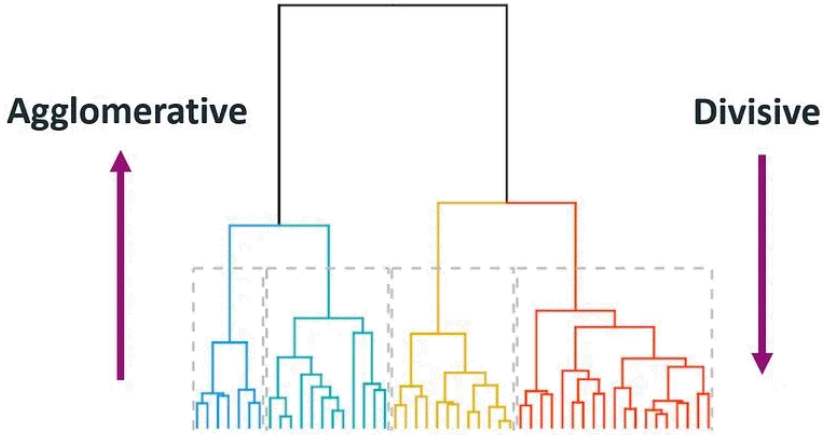
Proximity Analysis

- Generate the buffers by POIs of metro stations
- Dissolve the buffers, and identify areas surrounding metro stations



Space Syntax

- Correct and simplify the network topology by OSMnx
- Analyze synergy by DepthmapX



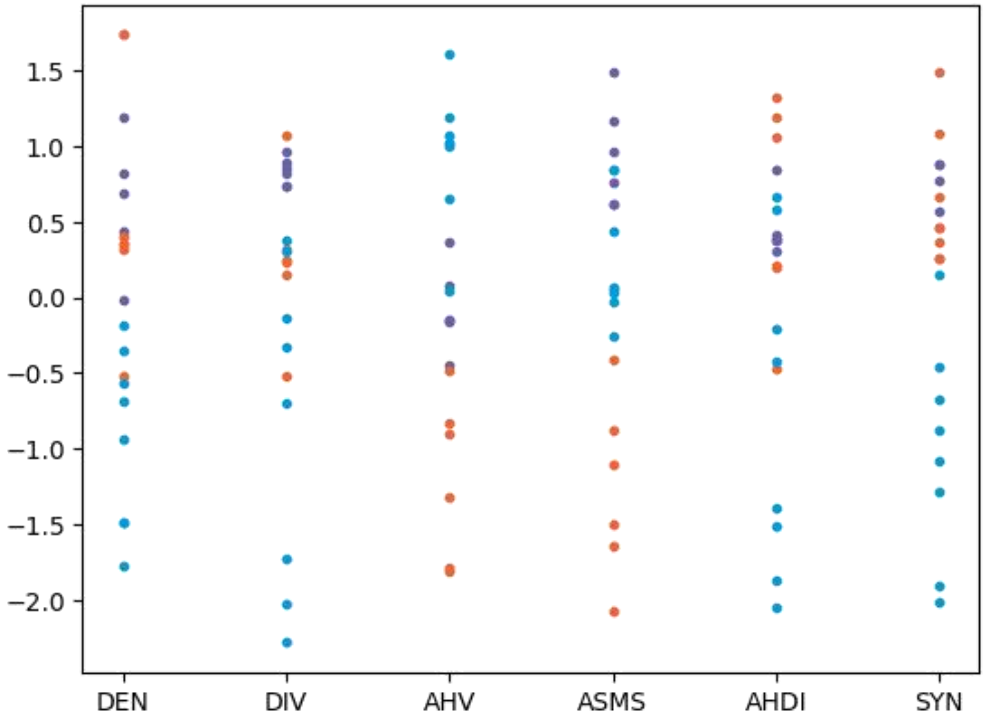
Hierarchical Cluster Analysis

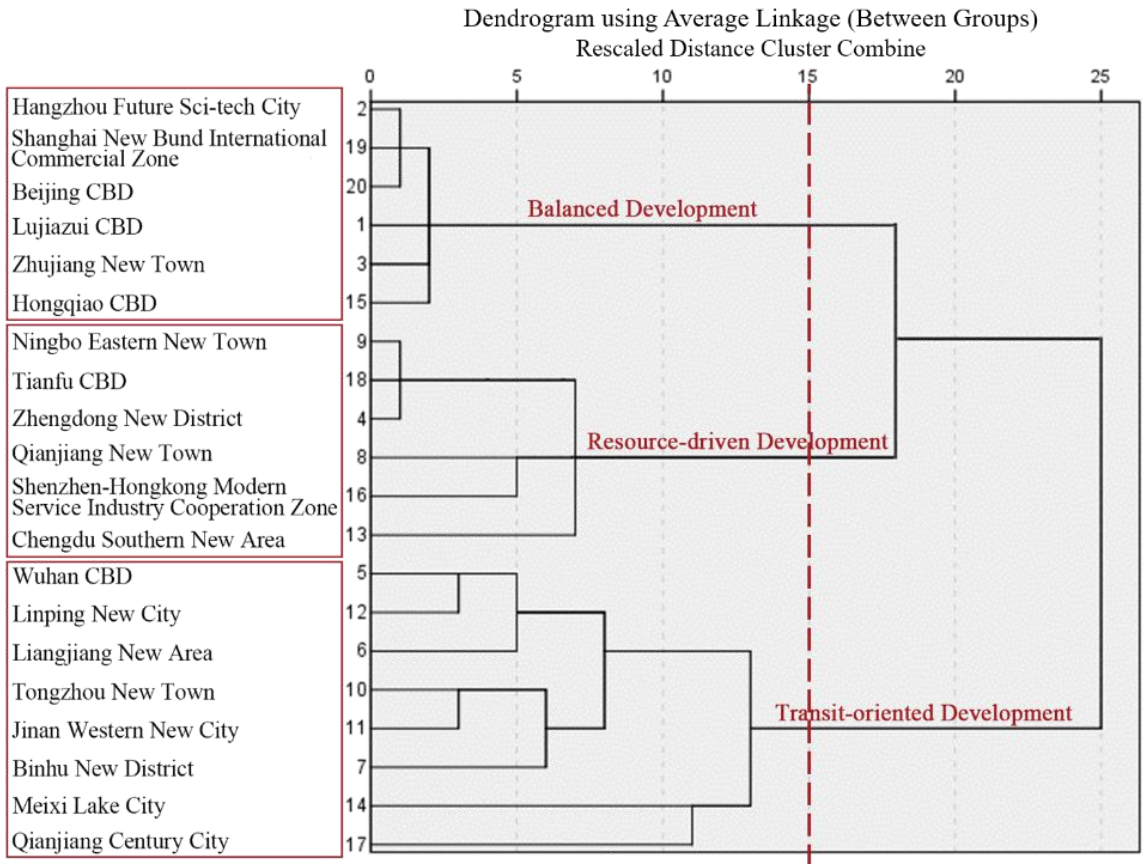
- Standardized with Z-score firstly
- Implemented based on the Between-groups linkage to Squared Euclidean Distance
- Investigate the typology of morphology and corresponding characteristics

Result

According to the clustering results, it is classified into three major categories:

- **Balanced Development (BD)**
- **Resource-driven Development (RDD)**
- **Transit-oriented Development (TOD)**





To facilitate identification of unique characteristics

- ☐ Generate visualizations of the Z-score normalized data.
- ☐ Analyze indicators performance of each typology.

Result

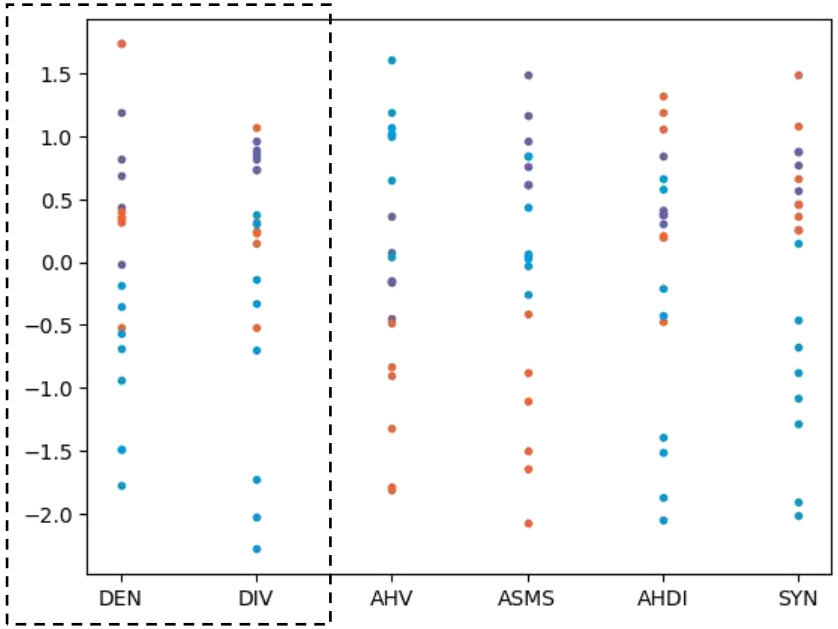
Land Use

Land Use Density (DEN)

- **BD** and **RDD** exhibit higher value compared to **TOD**.
- **BD** is more concentrated, while **RDD** and **TOD** show disperse data.

Land Use Diversity (DIV)

- **BD** and **RDD** provide great functional diversity, serving as a valuable complement to ground space.
- **TOD** spaces are relatively limited in these capabilities.



- **Balanced Development (BD)**
- **Resource-driven Development (RDD)**
- **Transit-oriented Development (TOD)**

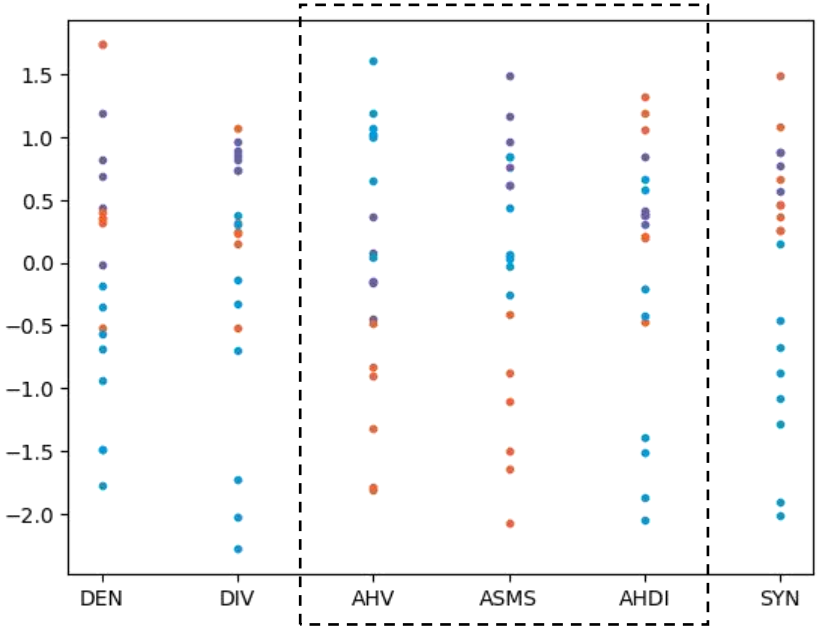
Result

Spatial Distribution

Areas of high vitality (AHV)

RDD is characterized by the **limited availability** of AHV.

- To a certain extent, it is affected by the **measurement of vitality indicators.**
- It may be related to **functions of space**, such as underground cultural space, sporting space, office space…



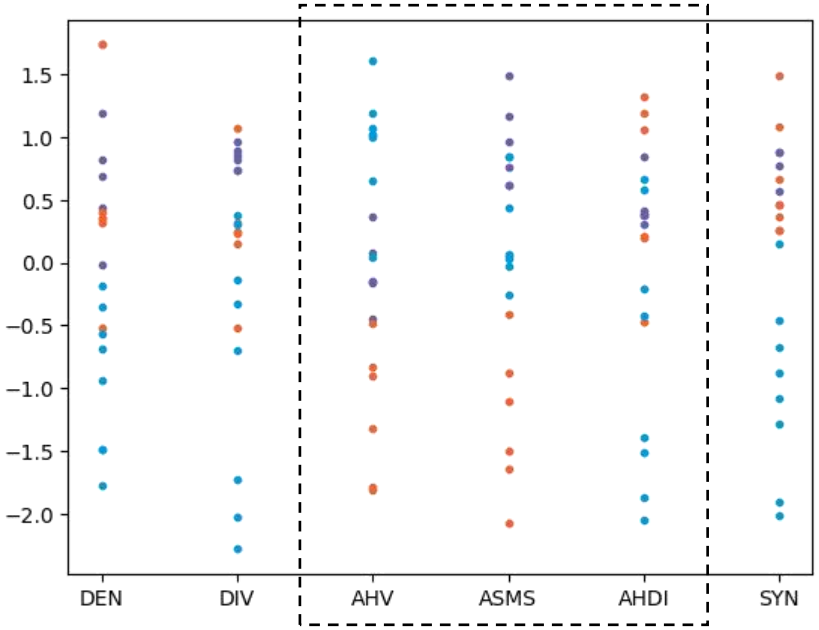
- **Balanced Development (BD)**
- **Resource-driven Development (RDD)**
- **Transit-oriented Development (TOD)**

Result

Spatial Distribution

Areas surrounding metro stations (ASMS)

- **TOD** has higher values in both AHV and ASMS, which confirms **the impact of metro development** on **the vitality of neighborhood scope**.
- **BD** is more **centrally** located within metro station areas, while **RDD** is relatively **more dispersed** outside ASMS.



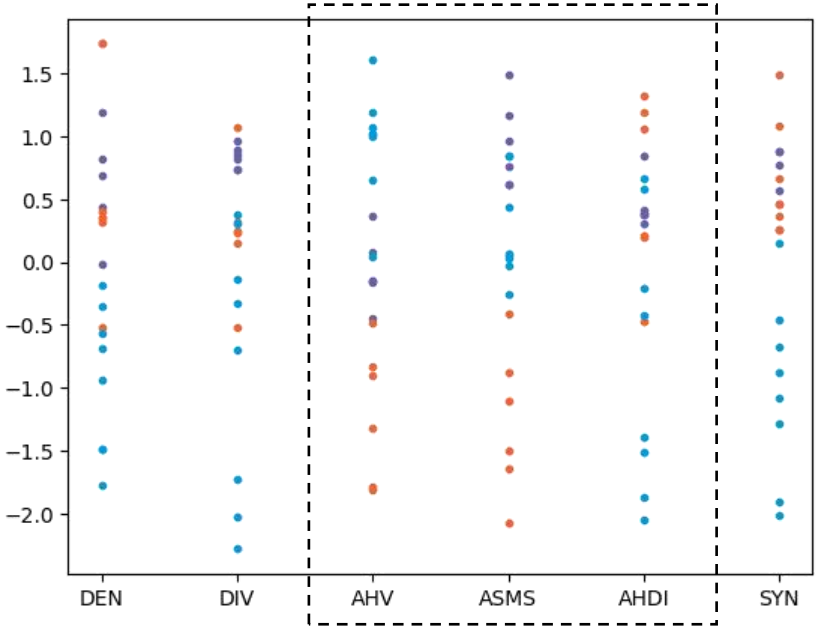
- **Balanced Development (BD)**
- **Resource-driven Development (RDD)**
- **Transit-oriented Development (TOD)**

Result

Spatial Distribution

Areas of high development intensity (AHDI)

- **RDD** is typically prevalent in AHDI, catering for **the needs of parking and public services**.
- Some **TOD**s display lower levels in AHDI, which can be attributed in part to **building density**.



- **Balanced Development (BD)**
- **Resource-driven Development (RDD)**
- **Transit-oriented Development (TOD)**

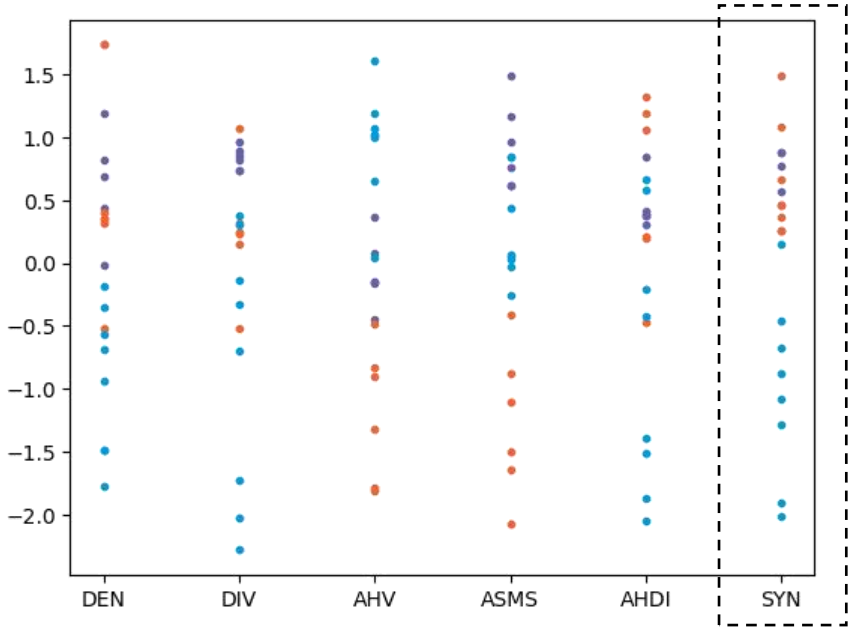
Result

Street Network

Synergy (SYN)

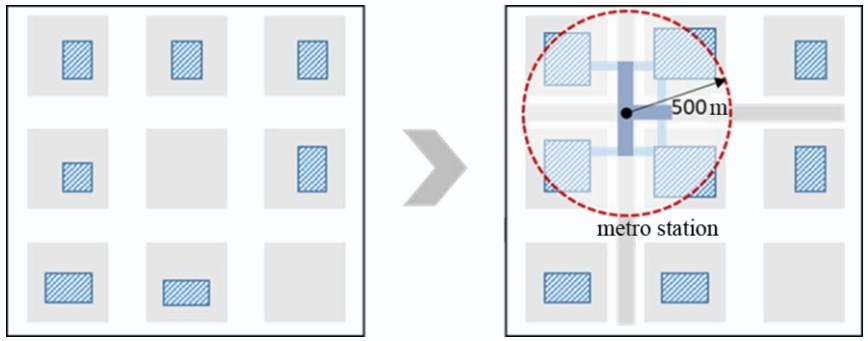
RDD and **BD** generally exhibit superior **synergy** than **TOD.**

- **RDD** and **BD** are typically more **condensed and morphologically consistent.**
- **TOD** is often **networked and feature multiple cores.**



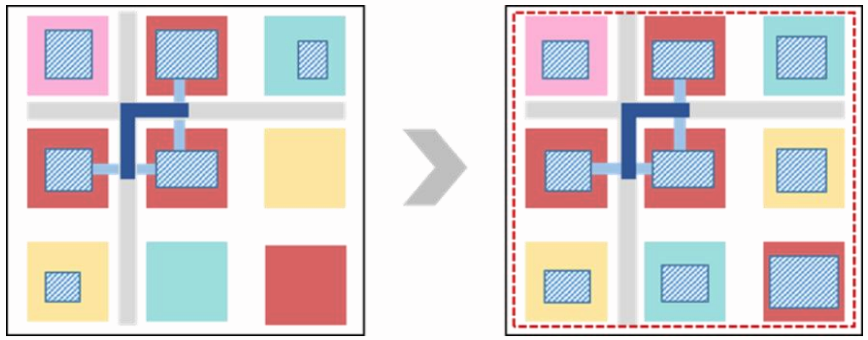
- **Balanced Development (BD)**
- **Resource-driven Development (RDD)**
- **Transit-oriented Development (TOD)**

Discussion



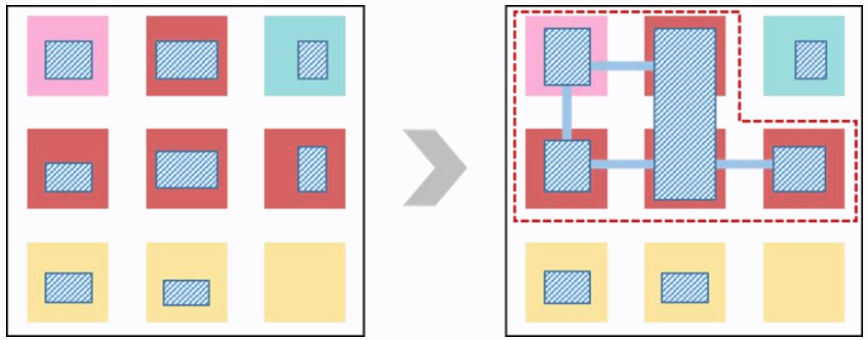
Transit-oriented Development (TOD)

It is primarily devoted to **transportation purposes**, with **underground commercial activities** surrounding metro stations exhibiting greater **vitality**.



Resource-driven Development (RDD)

This is conducive to the creation of underground spaces with **mixed functions** and **high development intensity**, but may lead to **fragmentation** and **lack of vitality**.



Balanced Development (BD)

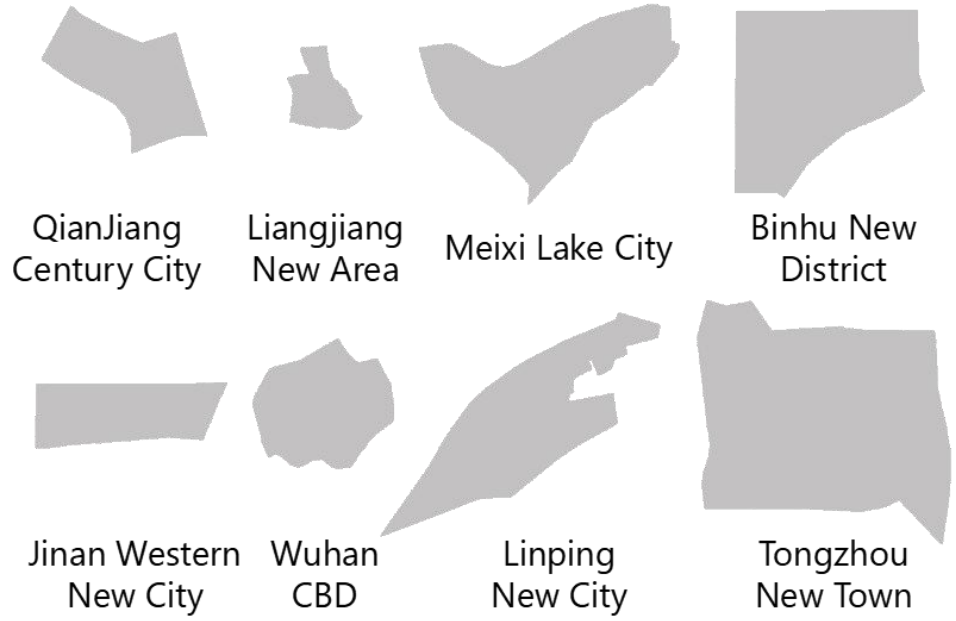
It represents **a balance** between **resource demand** and **transit orientation**. Surface resources and land usage is **fully considered,** incorporating high development intensity and functional diversity.

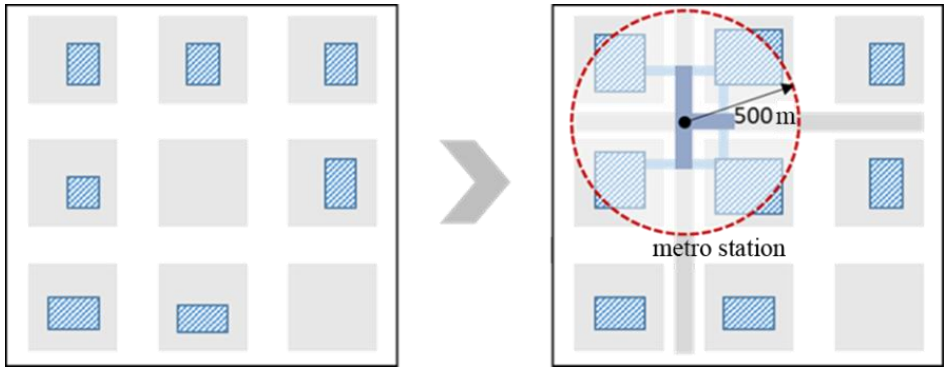
Discussion

Transit-oriented Development (TOD)

- It was primarily devoted to **transportation purposes**, with **underground commercial activities** surrounding metro stations exhibiting greater **vitality**.

- **Connectivity** between parcels **were difficult to implement** in the actual project, resulted in low development density and functional diversity.

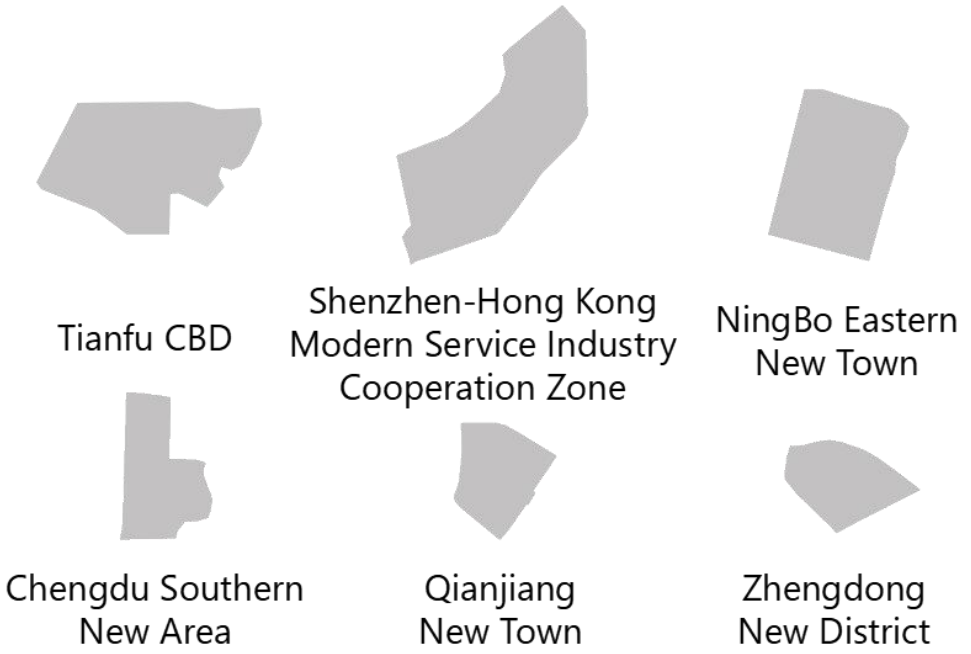


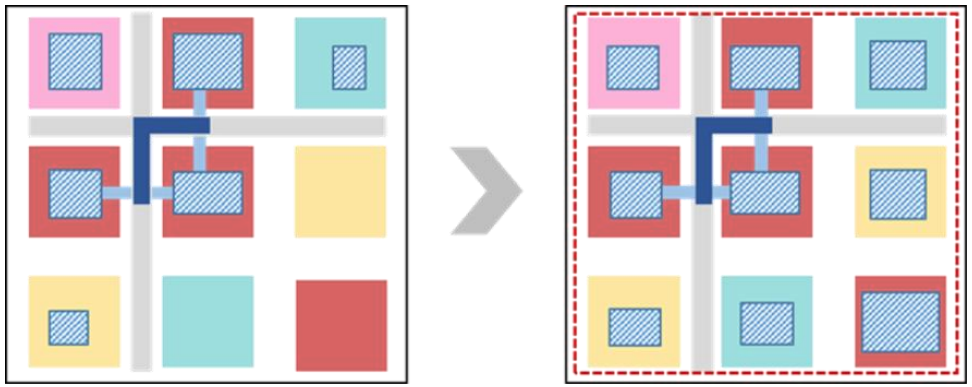


Discussion

Resource-driven Development (RDD)

- Many significant public centers **supplemented resource requirements** by underground space.
- This is due to factors such as restrictions caused by **height limitations**, **green space**, and **insufficient land resources**.
- **Diverse functions are extended downwards buildings**, resulting in the creation of underground commercial streets and parking space with **high development intensity**.



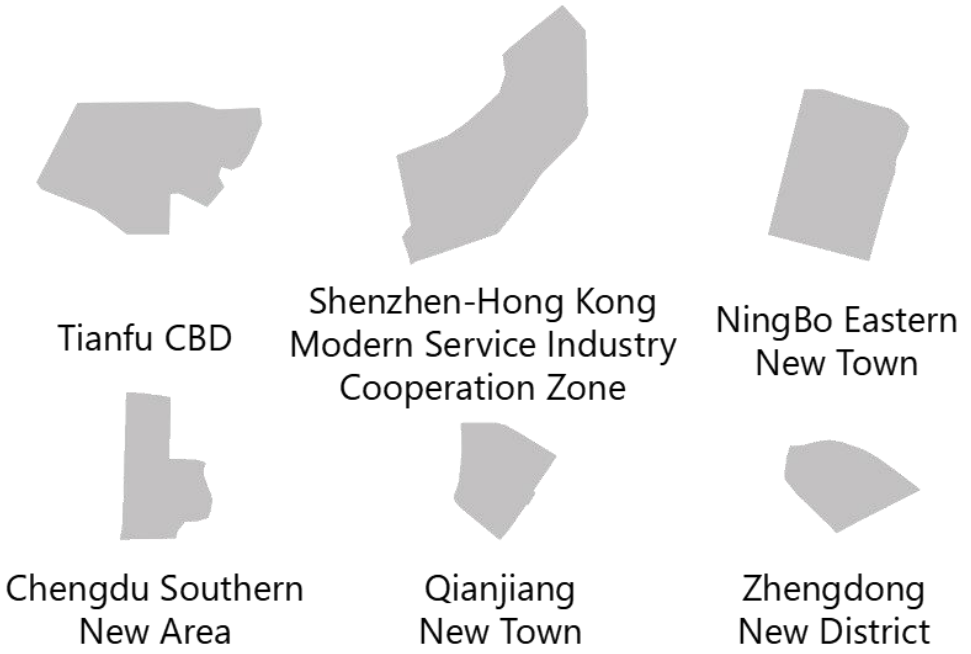


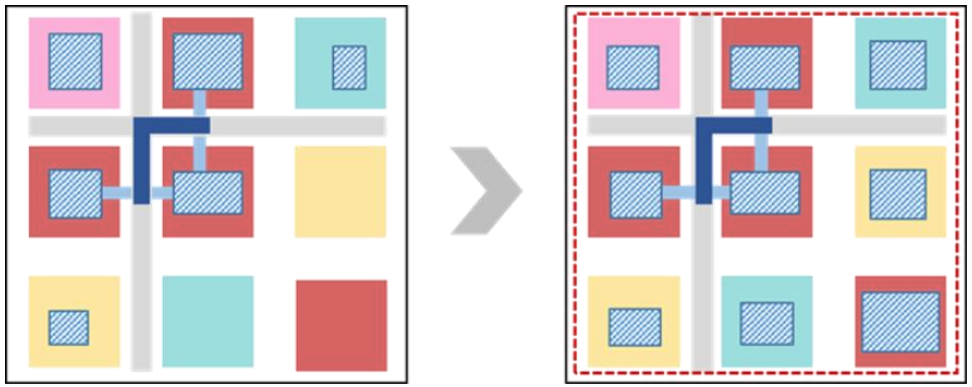
Discussion

Resource-driven Development (RDD)

- This is conducive to the creation of underground spaces with **mixed functions** and **high development intensity**, but may lead to **fragmentation** and **lack of vitality**.

- Integrated development in **major public centers** and **large green open spaces** to supplement ground-level requirements is advocated, in pursuit of **high vitality and resource sharing.**

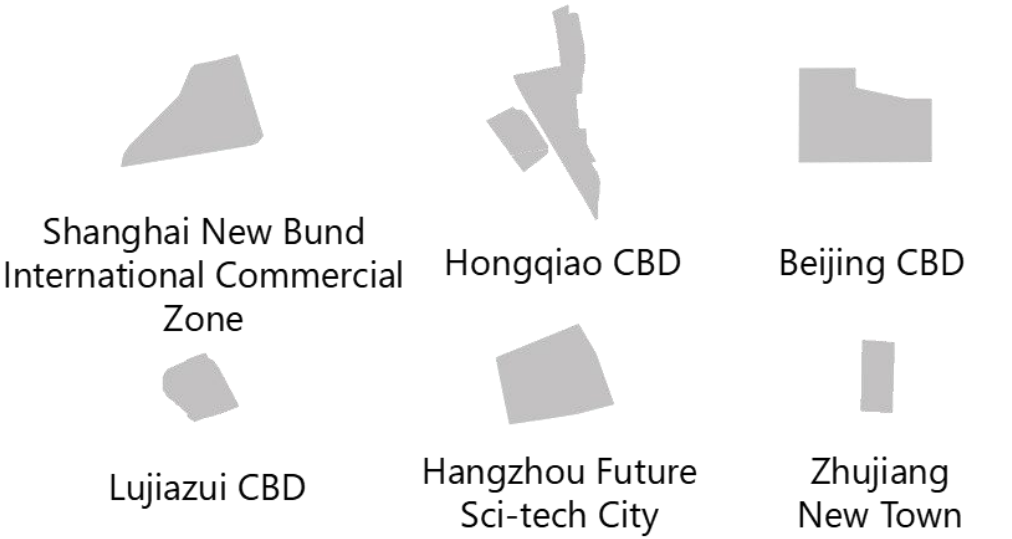


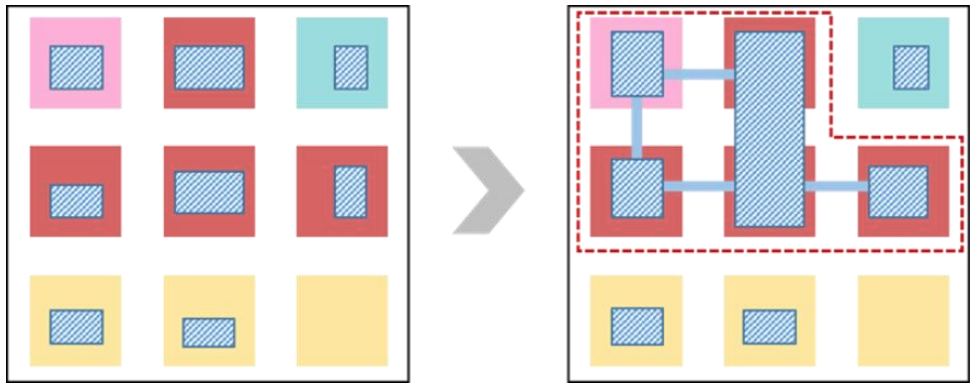


Discussion

Balanced Development (BD)

- It represented **a balance** between **resource demand** and **transit orientation**.
- Surface resources and land usage is **fully considered**, incorporating **high development intensity** and **functional diversity.**
- It is **not the ultimate objective**, for excess development may result in wastage of resources.





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Thanks for your attention!

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