The socioeconomic impact of land use policy and metro investment in urban India:
Through remote sensing floor-area-ratio detection

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*In memory of **Ravi Ponnapureddy**, our co-author who passed after a protracted battle with COVID-19. We express much gratitude to his kindness, his dedication to our study, and our excellent partnership.*

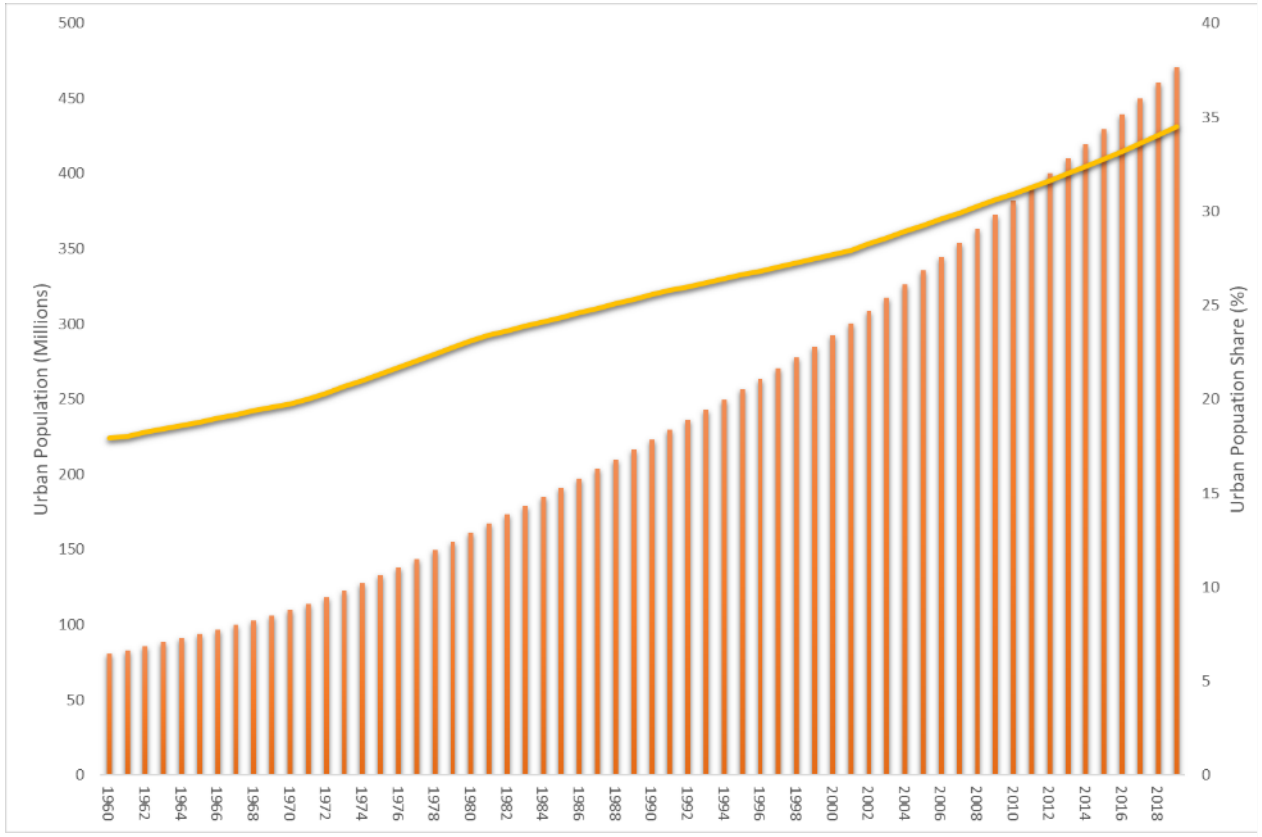
May he rest in peace.

Study objective

- **How can transport investment and complementary policies act together to promote cities as a thriving labor market?**

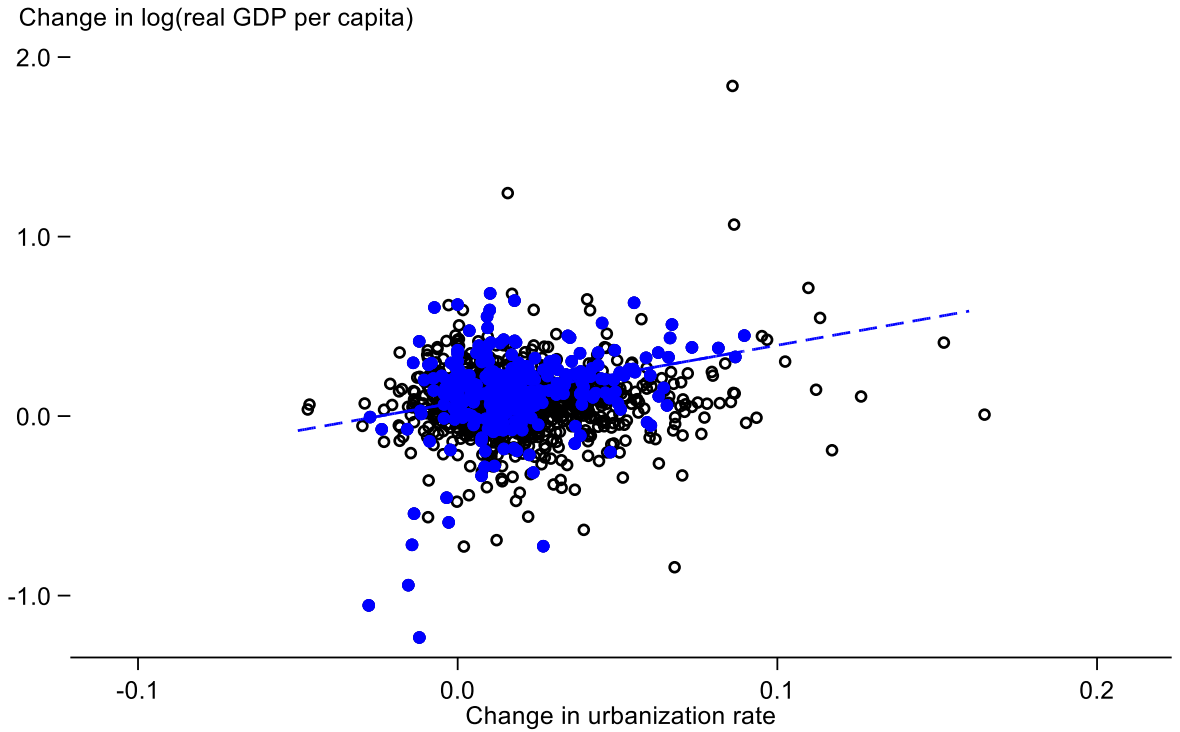
- This study quantifies how floor-area-ratio (FAR) relaxation can be an effective mechanism to maximize the economic benefits of a metro system.
  - The study uses remote-sensing technology to compare the urban form growth patterns in India and other international cities, especially along metro corridors.
  - Scenario-based simulation exercise examine how a variety of city-level socioeconomic outcomes are influenced by FAR regulations in the context of metro rail, particularly through densification.

Motivation: Growth and Urbanization



Urban Population in India

Source: World Bank

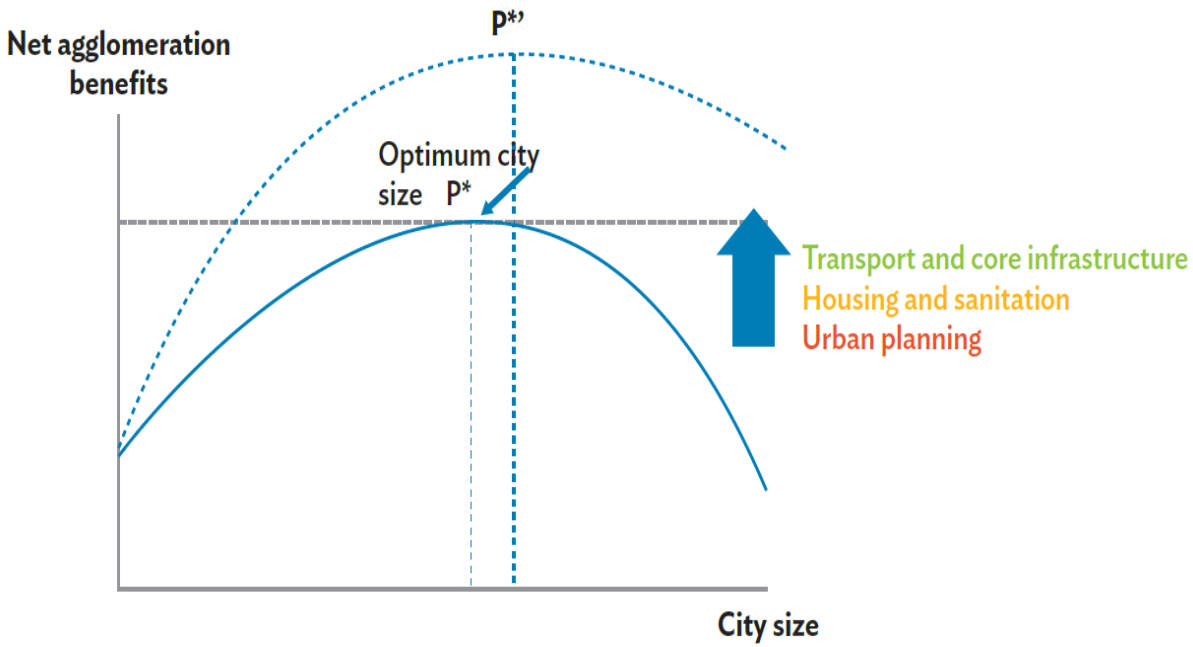


Source: ADB estimates based on UN (2018) World Bank (2019).

India is rapidly urbanizing.

Link between urbanization and economic growth.

Balancing Agglomeration and Congestion Forces



Source: Adopted from Duranton (2008).

Net Agglomeration Benefits and the Basic Agenda for Managing Cities

Agglomeration economies encourage firms and households to move to a city—making it larger

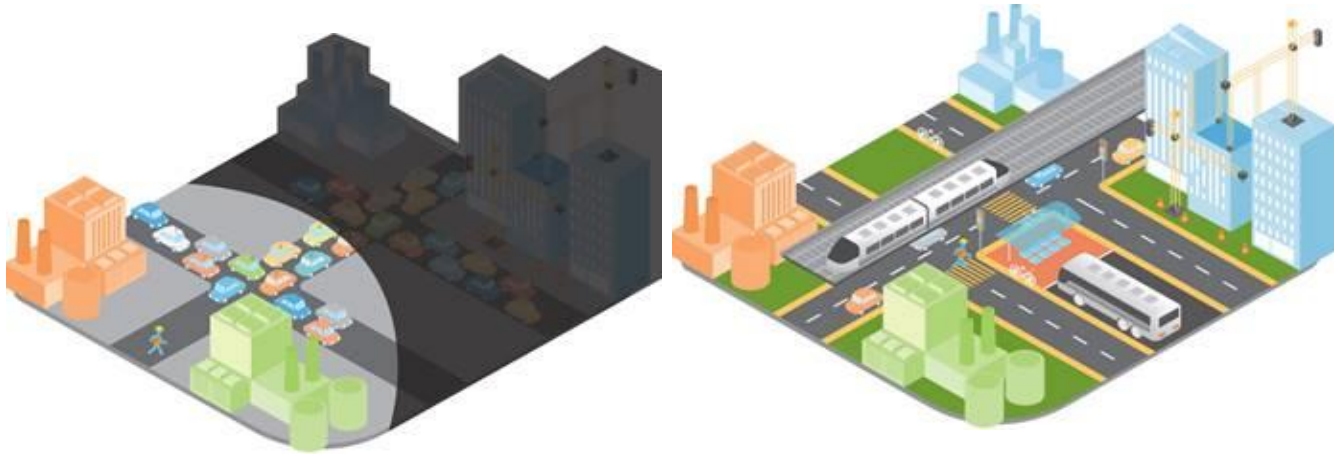
Congestion can short circuit these processes and lead to loss in productivity.

Three key conditions:

- Travel within the city is fast and cheap.
- Firms and households have flexibility to relocate within the city.
- Real estate is relatively affordable.

Low mobility scenario

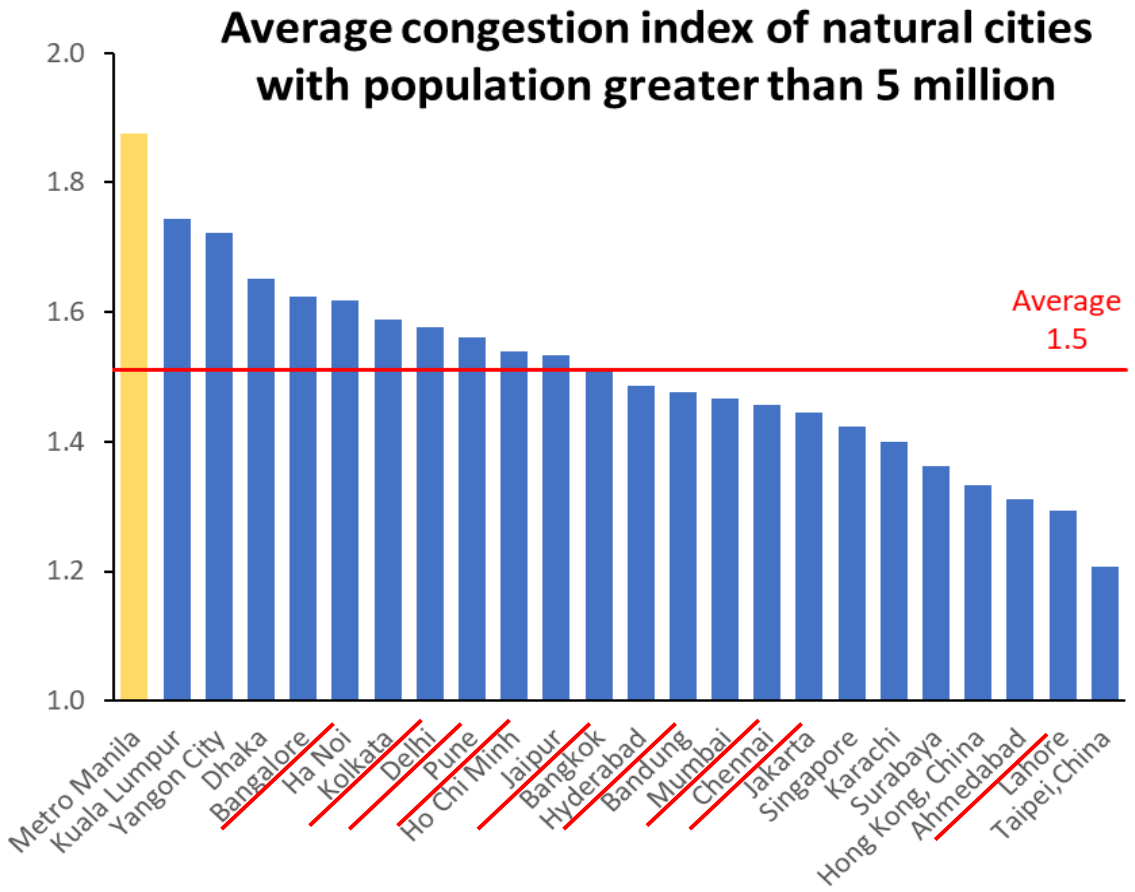
High mobility scenario



Source: Adopted from Bertaud (2018)

But the link is not always guaranteed…

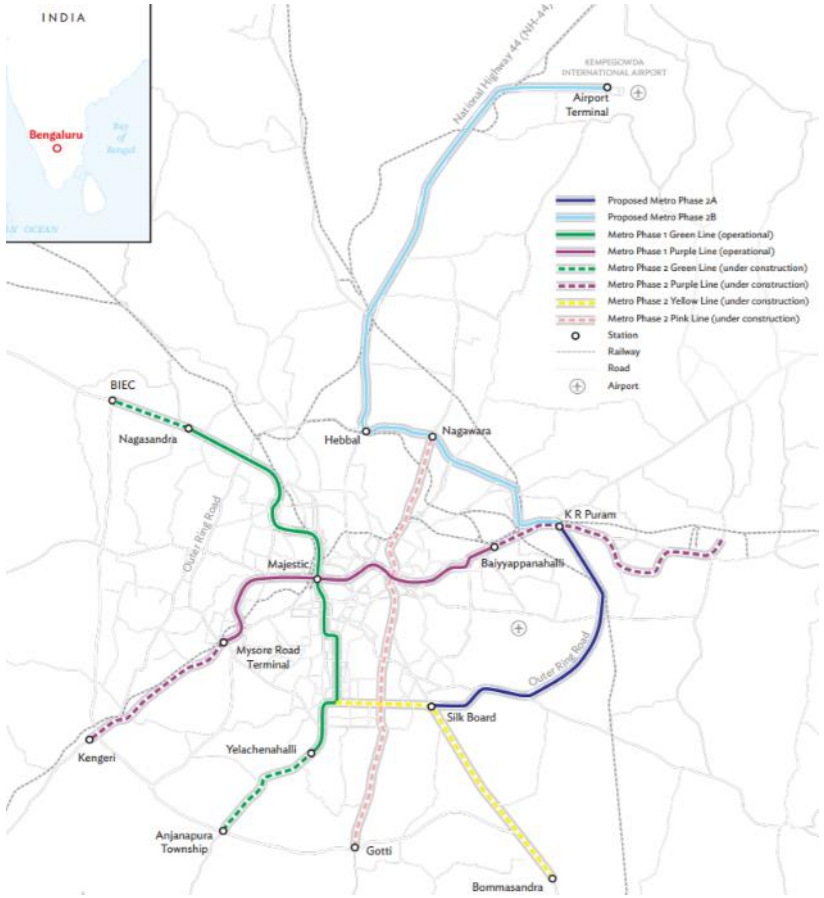
Is travel within the city fast and cheap?



Source: ADB (2019) estimates using Google Maps.

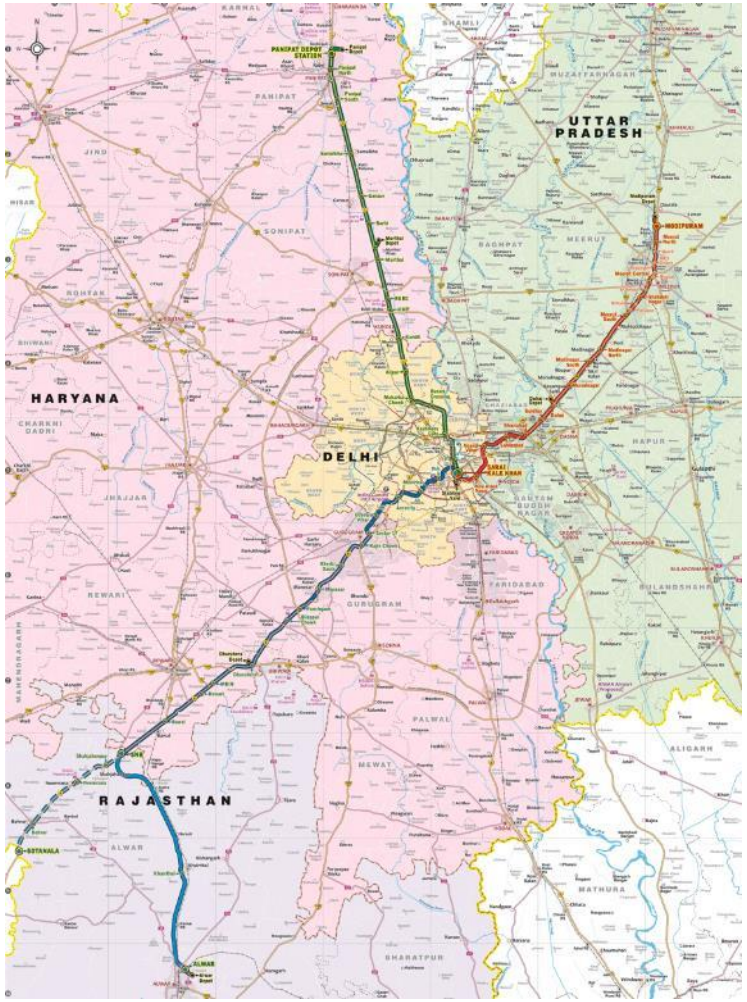
Indian cities are among the slowest in Asia.

Many large Indian cities have selected metro rail systems as the backbone of mass transit system



Namma Metro

Mumbai Metro



Regional Rapid Transit System (RRTS)

Is relocation within the city flexible and affordable for households and firms?

Center-city FAR values.
Source: World Bank (2012).

City	FAR
Sao Paulo	1
Mumbai	1.33
Chennai	1.5
Delhi	1.2–3.5
Amsterdam	1.9
Venice	2.4
Paris	3
Shanghai	8
Vancouver	9
San Francisco	9
Chicago	12
Hong Kong	12
Los Angeles	13
New York	15
Denver	17
Tokyo	20
Singapore	12–25

Indian cities have much more strict building height restrictions than other international cities.

Zoning of Land Use and Regulations Bengaluru Master Plan 2015

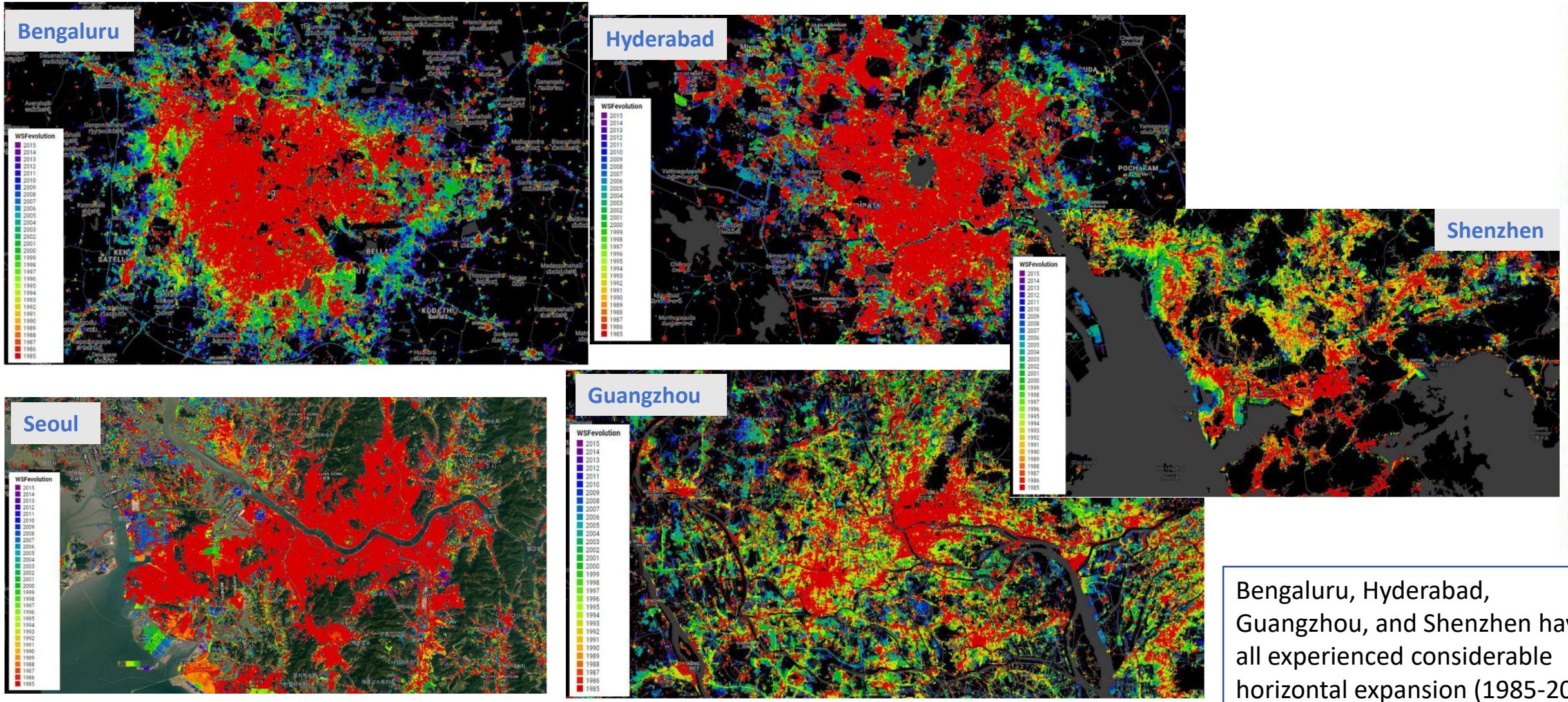
Table 10: FAR and Ground Coverage in Residential (Main)

Sl.No.	Plot size (sq.m)	Ground Coverage. (Max)	FAR	Road width (m)
1.	Up to 360	Up to 75 %	1.75	Up to 12.0
2.	Above 360 up to 1000	Up to 65 %	2.25	Above 12.0 up to 18.0
3	Above 1000 up to 2000	Up to 60 %	2.50	Above 18.0 up to 24.0
4.	Above 2000 up to 4000	Up to 55 %	3.00	Above 24.0 up to 30.0
5.	Above 4000 up to 20000	Up to 50 %	3.25	Above 30.m

Table 14: FAR and Ground Coverage in Commercial (Business) up to 12000 sq.m

Road width (m)	FAR	Coverage
Less than 9	1.50	55 %
Above 9 and up to 12	1.75	50 %
Above 12 and up to 18	2.25	50%
Above 18.0 up to 24.0	2.50	45 %
Above 24.0 m up to 30.0	3.00	40 %
Above 30.0 m	3.25	40 %

A simulation-based case study in Bengaluru
Urban form comparison (vertical and horizontal) using remote sensing data



Bengaluru, Hyderabad, Guangzhou, and Shenzhen have all experienced considerable horizontal expansion (1985-2015).

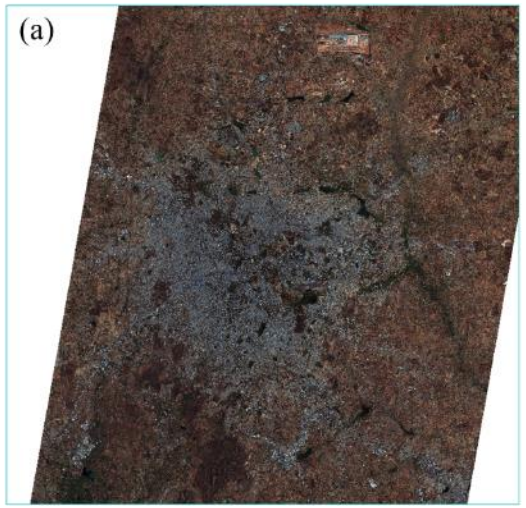
Horizontal expansion: Impervious area 1985-2015

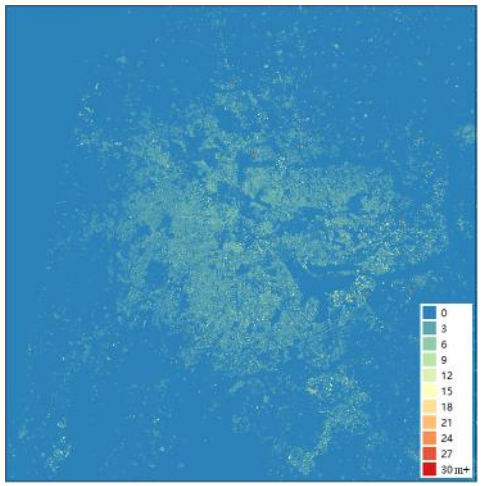
Data source: WRI estimation based on DLR WSF-imperviousness and DLR WSF-Evolution.

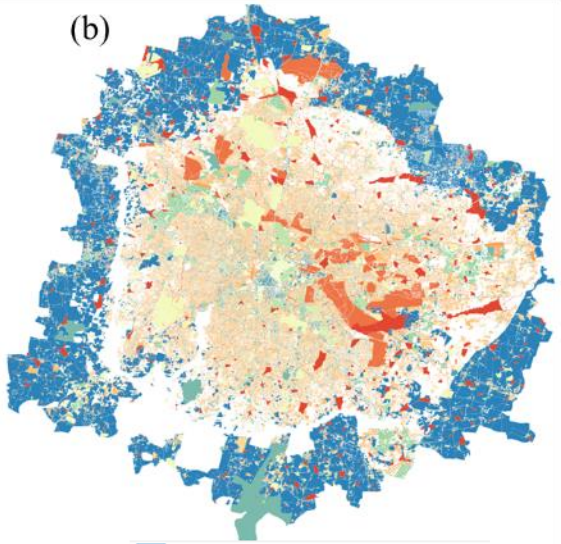
A simulation-based case study in Bengaluru
Urban form comparison (vertical and horizontal) using remote sensing data

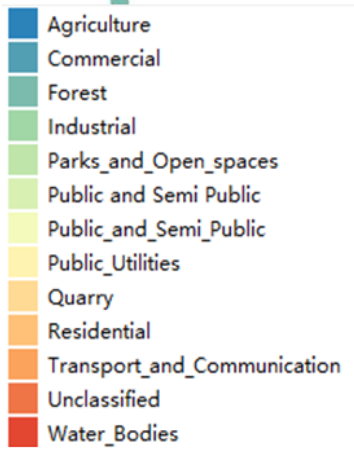
Bengaluru

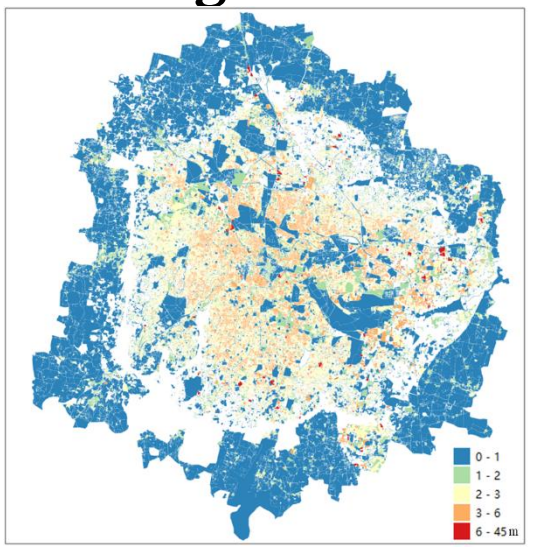
2km x 2km image

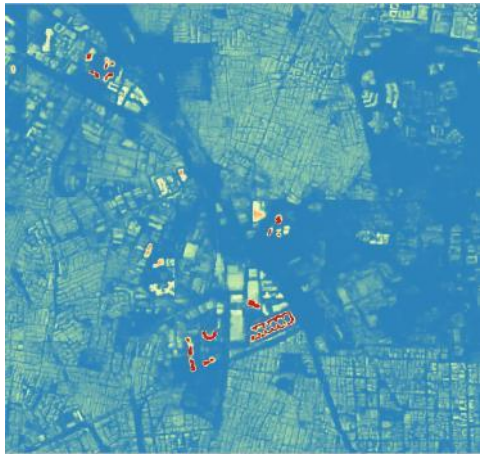


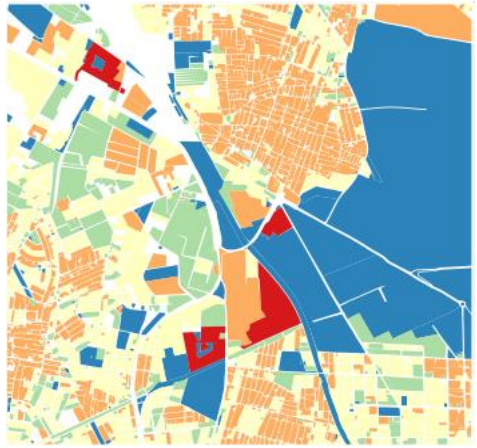












(a) Remote sensing net-Digital Surface Modal (nDSM) images → M3Net Deep Learning Predicted building height

(b) Digitized land use → (a) + (b) → (c) Building height of each land parcel

Data source: *(a-i) DLR WSF3D (ALOS DSM) – 30m x 30m – 2015 – estimation based (Esch et al., 2020)* *(b) Bengaluru Master Plan*
(a-ii) ZY-3 multi-view images – 2.5m x 2.5m – 2020 – multi-view DL based (Cao and Huang, 2021)

Urban form comparison (vertical and horizontal) using remote sensing data

Methodology

Baseline and counterfactual benchmark

- Compare the urban form (horizontal and vertical) of Bengaluru to Seoul and Shenzhen with remote sensing data.

Building height within 1km of Kempegowda Majestic

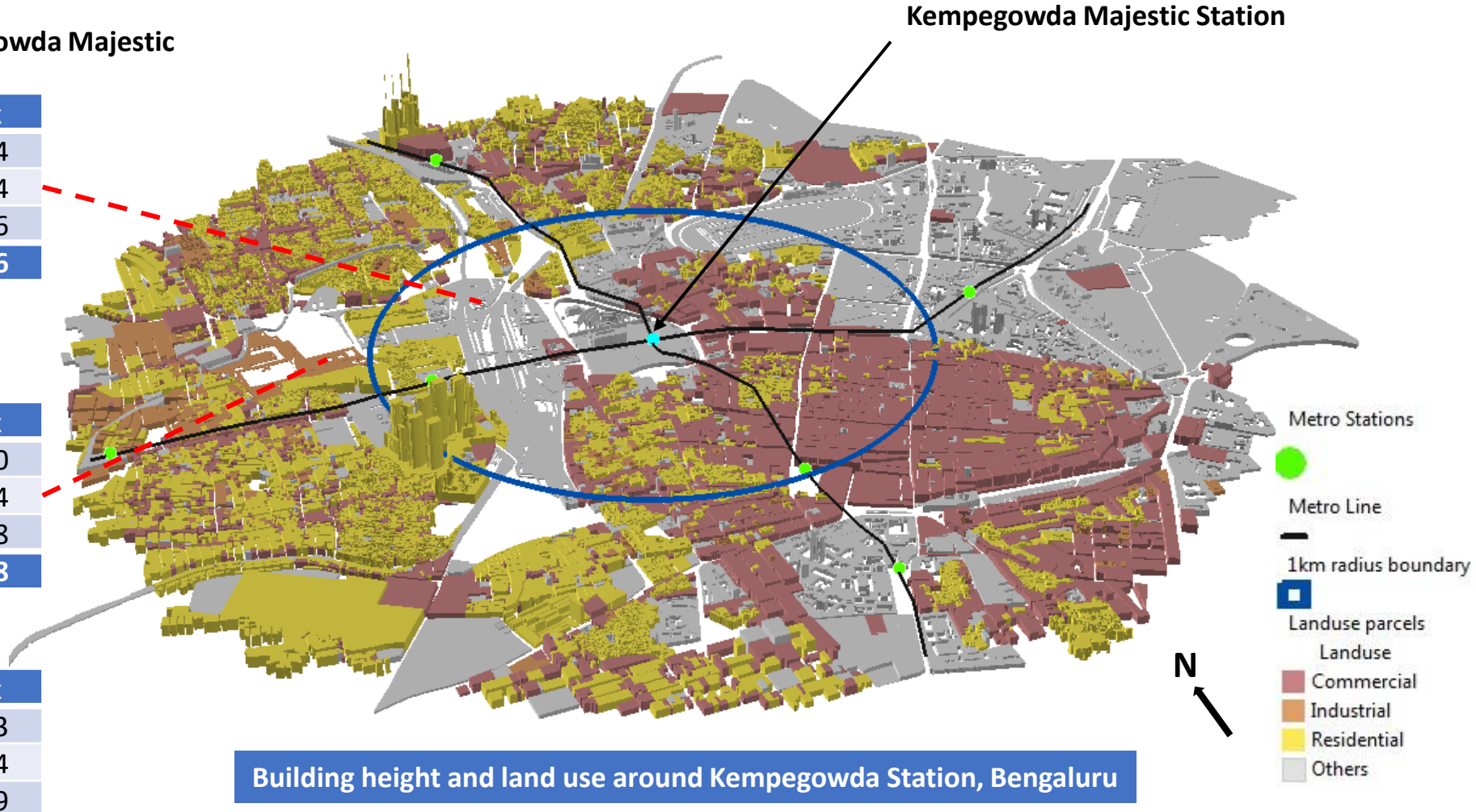
	Average	Max
Commercial	3.30	15.74
Industrial	3.43	11.74
Residential	3.01	60.06
All land use	**2.90**	**60.06**

Building height within 2km of Kempegowda Majestic

	Average	Max
Commercial	3.05	18.60
Industrial	2.95	11.74
Residential	3.06	68.58
All land use	**2.99**	**68.58**

Building height in Bengaluru

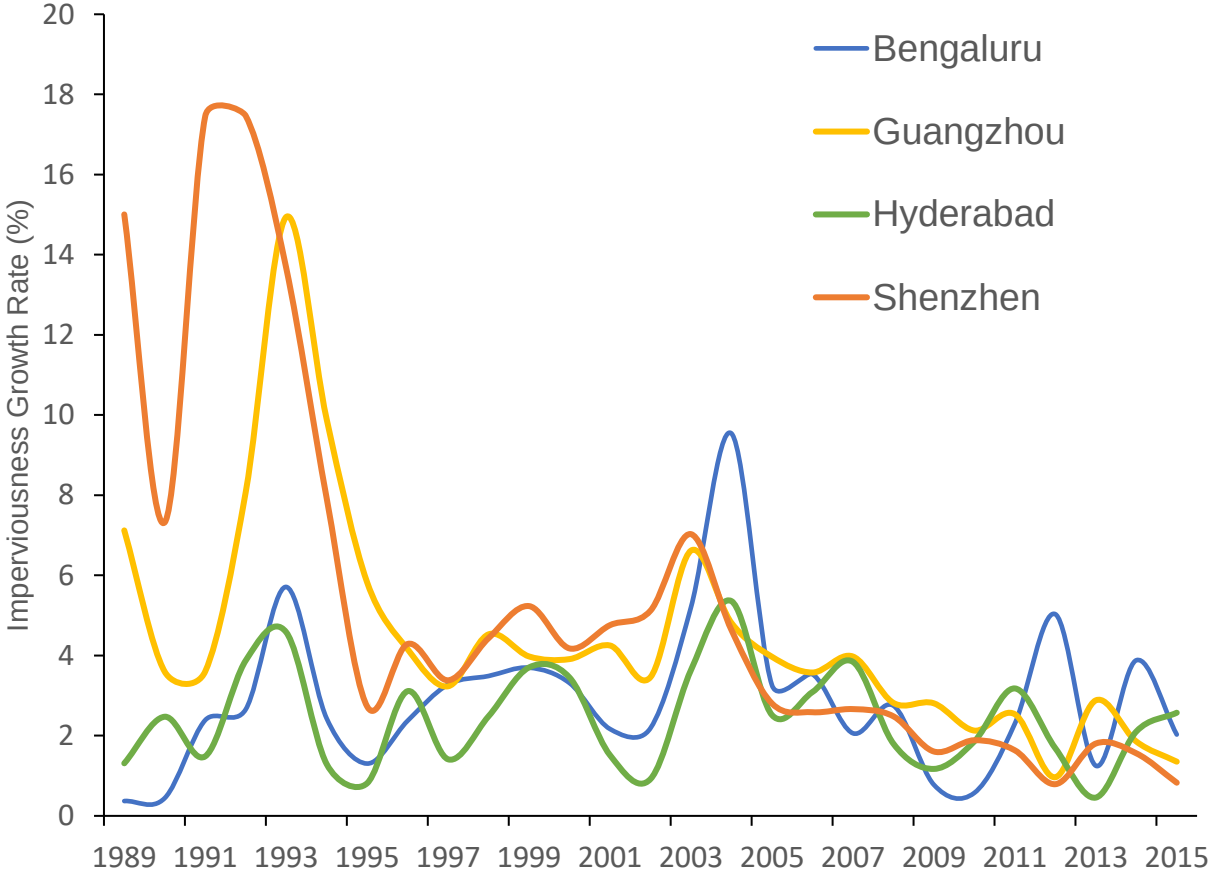
	Average	Max
Commercial	4.42	69.13
Industrial	4.33	49.64
Residential	4.29	82.19
All land use	**4.22**	**82.19**



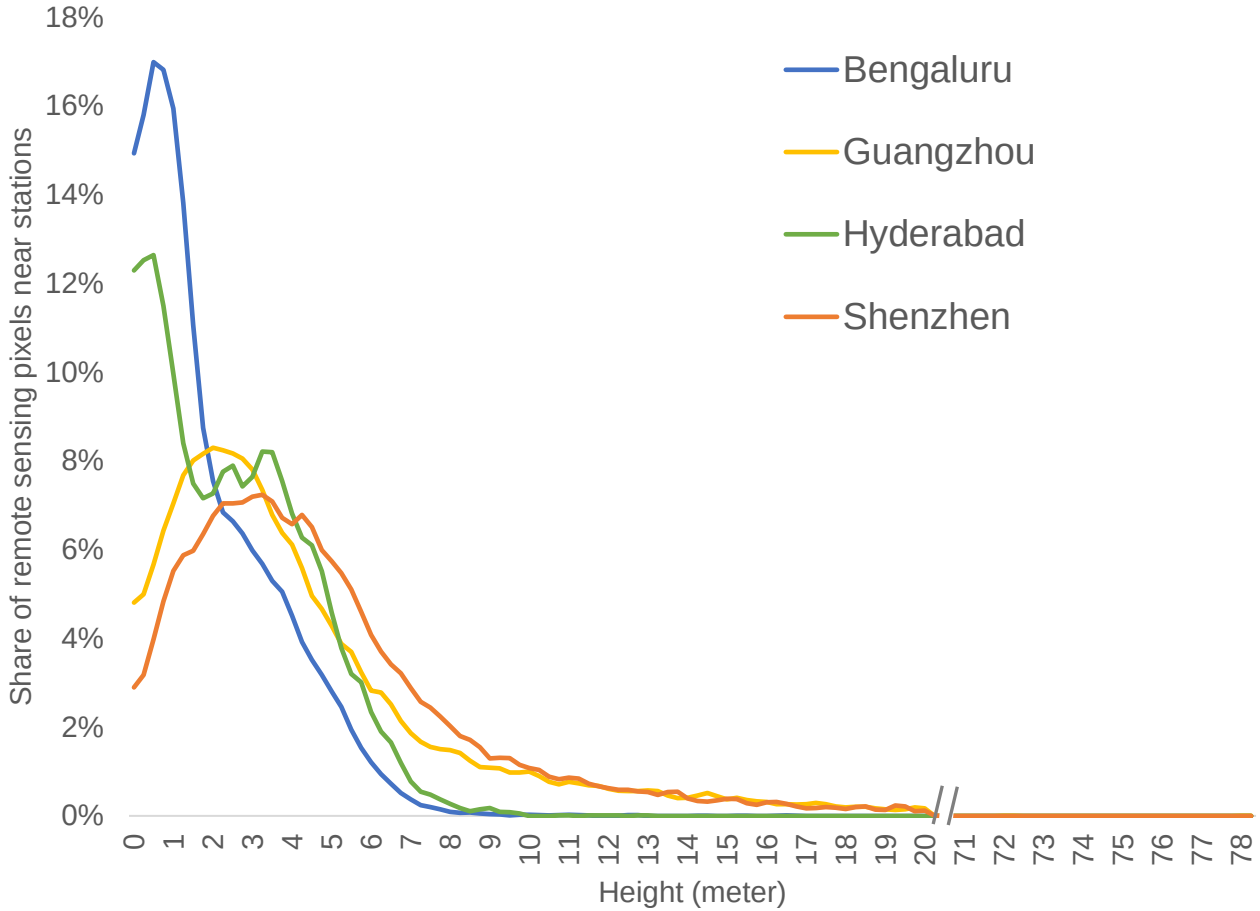
Building height and land use around Kempegowda Station, Bengaluru

Source: ADB estimates using ZY-3 multi-view images

Compared to other international cities, Indian cities have also expanded horizontally, but only with limited vertical growth.



Annual Impervious Area Growth Rate 1989 - 2015



Frequency distribution of remote sensing pixels by height around metro stations 2015

Source: DLR WSF3D 90m (using ALOS DSM), DLR WSF-imperviousness, DLR WSF-Evolution, OpenStreetMap, GADM boundary

International experiences and India's National TOD policy recommends densification, yet the implementation in India cities is uneven.

National TOD Policy Recommendations

i. Demarcation of the transit influence zone with a radius of 500–800 meters (m) from the transit station under the city's master plan and local area plans;

ii. Provision of a minimum floor area ratio (FAR) of 300%–500% or even higher depending on size of the city in the transit influence zone, and incorporation of variations in the FAR based on factors such as infrastructure carrying capacity, transit capacity, and zoning provisions;

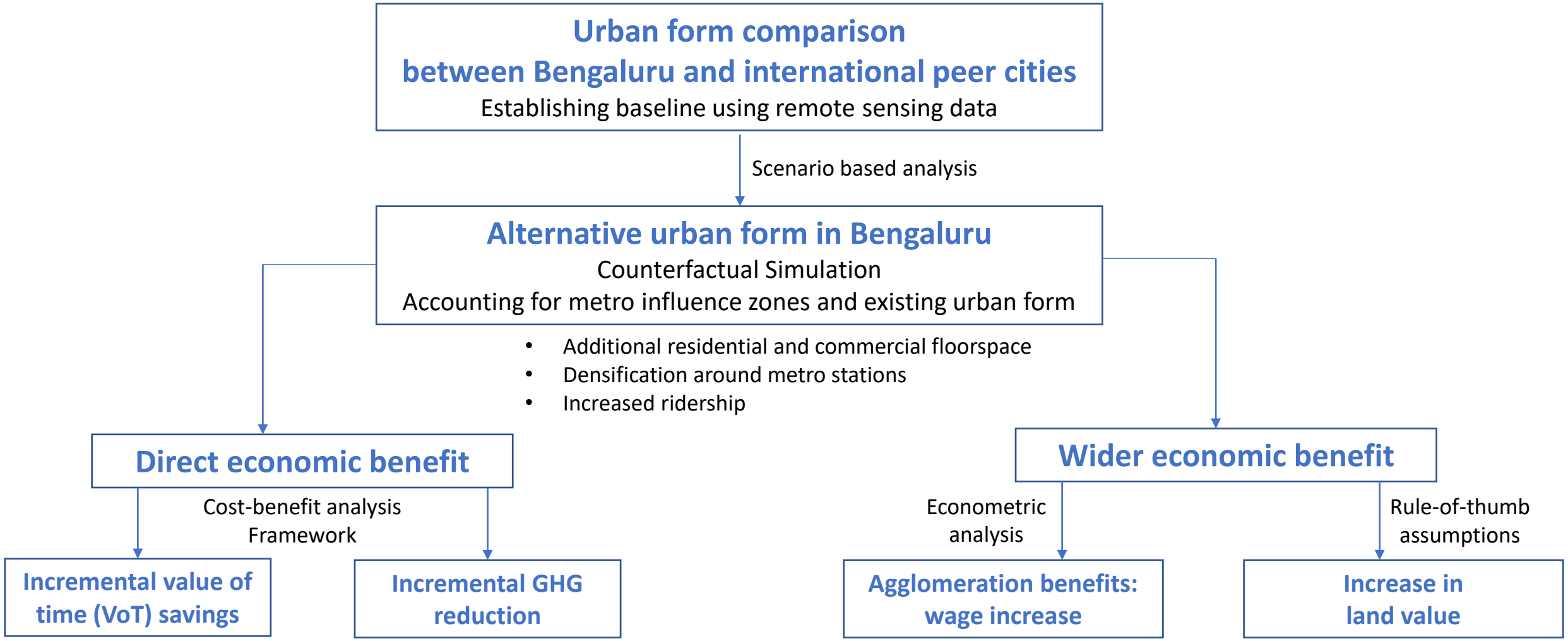
iii. Promotion of mixed-use development within the transit-oriented development (TOD) zone, with commercial activity on the ground floor and a minimum of 50% of the frontage being untinted and transparent.

Provisions for Increasing Density along Transit Networks

Provision	Ahmedabad	Bengaluru	Chennai	Delhi	Hyderabad	Kochi	Mumbai
Addition FAR over base values in TOD zone	122%	25%–50%	NA	50%	NA	NA	NA
Linkage of FAR with node-place values	No	Yes	No	No	No	No	No
Extent of the TOD zone	200 m	1,000 m (around station)	500 m (along corridor)	500 m (around station)	300 m (along corridor)	NA	NA
Provision for infrastructure augmentation	(along corridor)	Yes	No	Yes	No	No	No

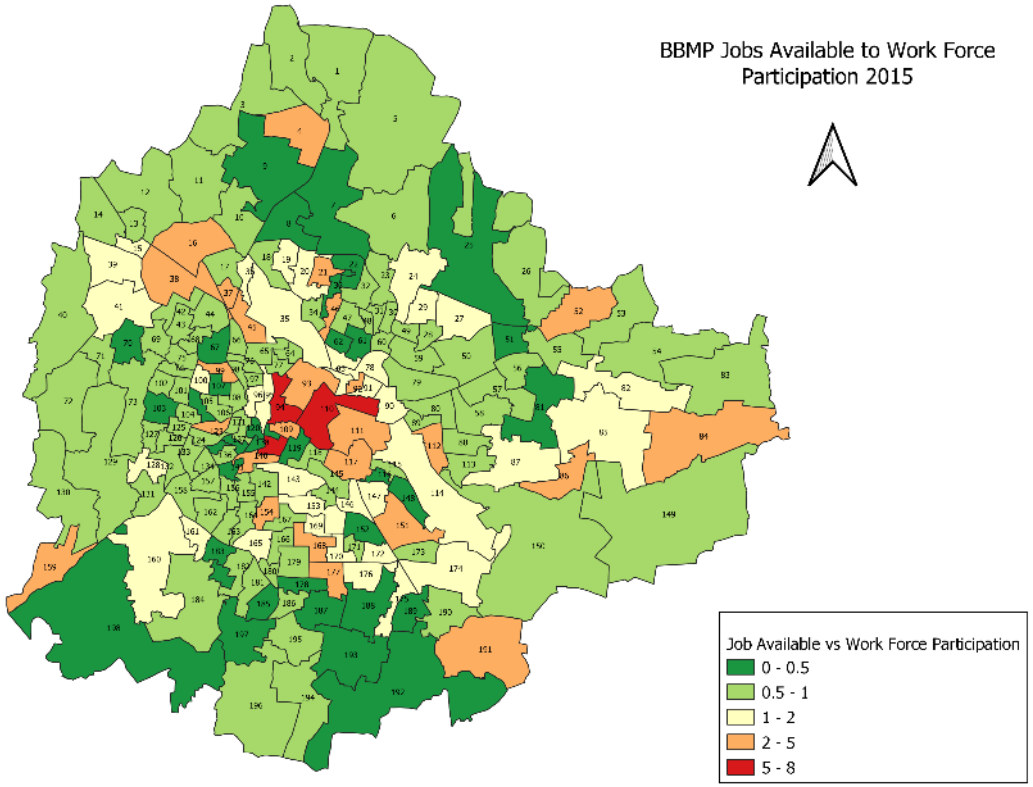
What would Indian cities gain by implementing the national TOD recommendations or following international best practices?

- **A simulation-based case study in Bengaluru**



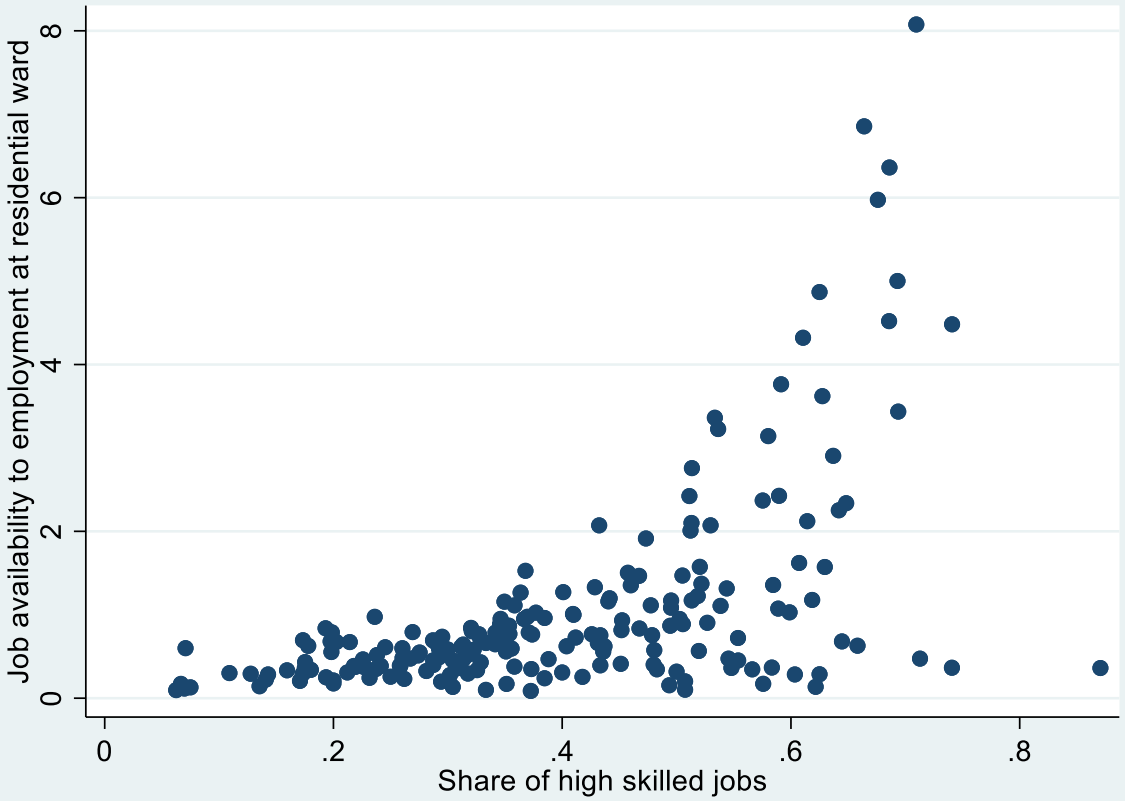
Urban form and socio-economic landscape

Job availability to work force participation ratio



Job availability is far from balanced across the city.

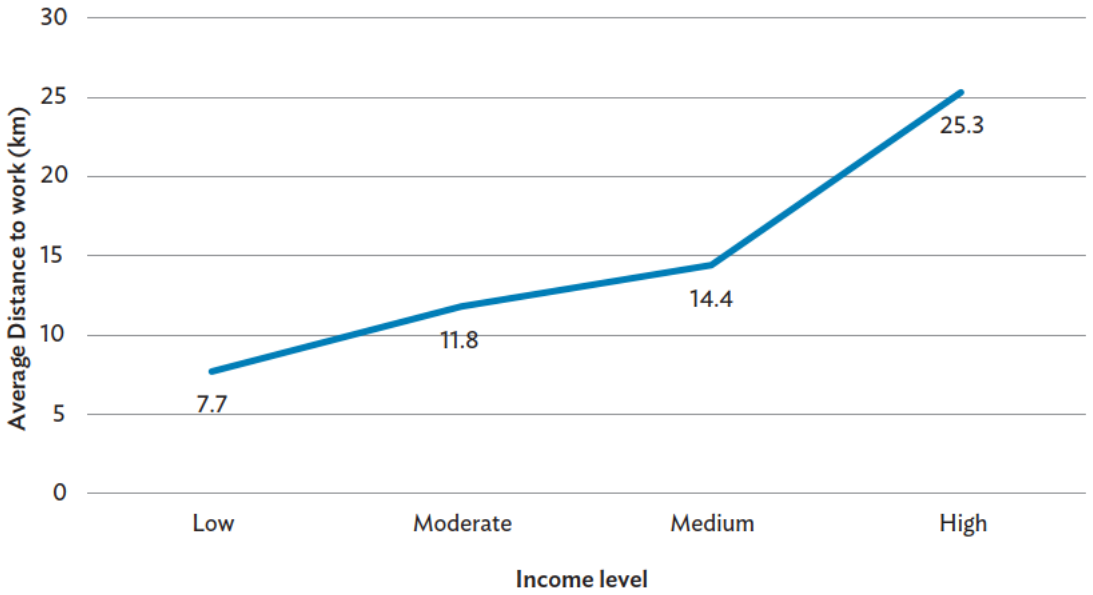
Share of high skilled jobs vs. job availability ratio

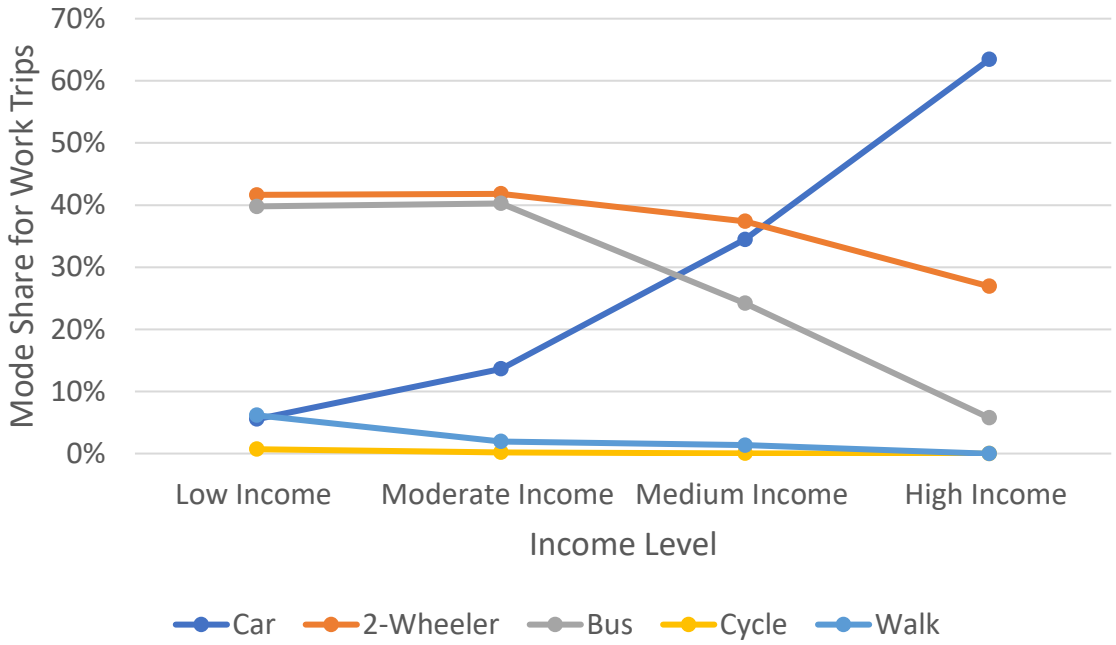


Locations with high job availability are characterized with higher share of high skilled jobs.

Note: The ratio indicates the number of jobs available over the number of employed at each ward. High skilled jobs denote jobs performed by colleague graduates.
Source: ADB estimates using Census Abstract 2011 and Bengaluru Travel Survey 2015.

Affordable public transport that provides fast and reliable commuting options could contribute towards reducing job accessibility inequality.





Lower income group tends to work closer to where they live, and relies on public transport and 2-wheelers to commute.

Time saved	Respondent households (#)	Percent
Up to 10 min	3,835	39.92
Up to 10–20 min	3,892	40.51
Up to 20–30 min	1,525	15.87
Unwilling to shift	355	3.70
Total	9,607	100.00

Most respondents are willing to shift to faster public transport.

Note: Low/Moderate/Medium/High income groups are defined by monthly income quantiles reported by Travel Survey.
Source: WRI estimates using Bengaluru Travel Survey 2015.

What would Indian cities gain by implementing the national TOD recommendations or following international best practices?

Alternative urban forms for Bengaluru

a) Increase in FAR across the city

- Let Bengaluru expand vertically
- Bengaluru is overall as high as Seoul or Shenzhen
- Accounting for brown-field /green-field development (e.g., inside the Outer Ring Road)
- TOD influenced areas around metro stations (as recommended by National TOD Plan)

b) Increase in floorspace and population

- The increase in FAR translates into increase in residential and commercial floor space, which further translates into increased population.
- "Open city" assumption is adopted – perfectly elastic supply of migrants.

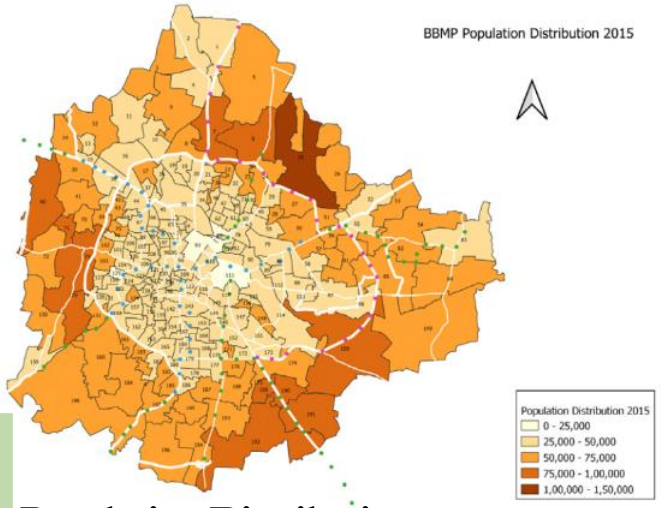
Scenarios

Seoul Regulatory FAR

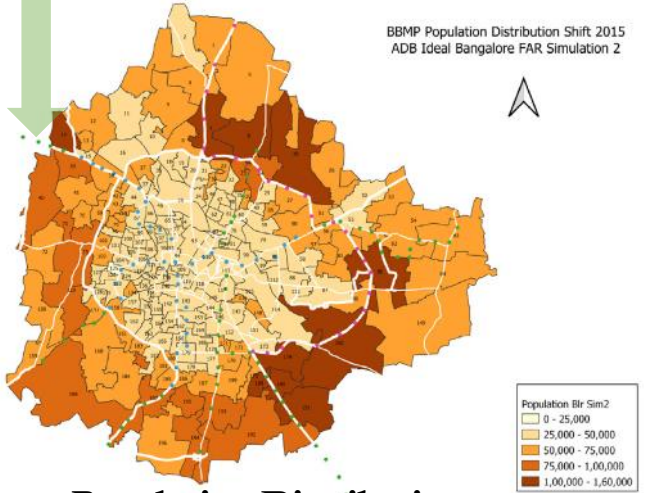
- Adjust FAR in Bengaluru up to regulatory FAR in Seoul.
- Areas around metro stations (1km range) and outside Outer-Ring Road gain more FAR.
- Two sub-scenarios considered for sensitivity:
  - **Intermediate adjustment**: Adjustment is done if 25% of a ward is within metro station influence zone.
  - **Aggressive adjustment**: Adjustment is done if any % of a ward is within metro station influence zone.

Shenzhen consumed FAR

- Adjust FAR in Bengaluru up to consumed FAR in Shenzhen.
- Consumed FAR in Shenzhen is based on remote sensing data.



Population Distribution
(Baseline)



Population Distribution
(Seoul simulation – open city)

Direct Economic Benefits

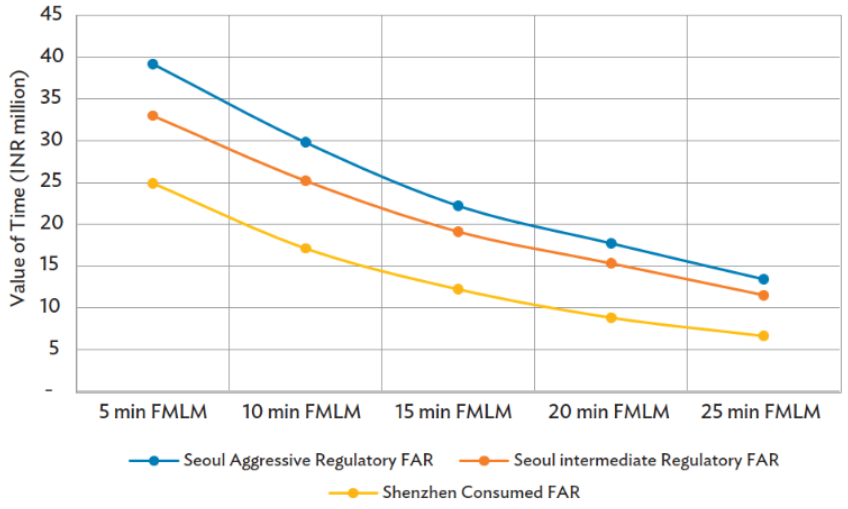
Direct economic benefits

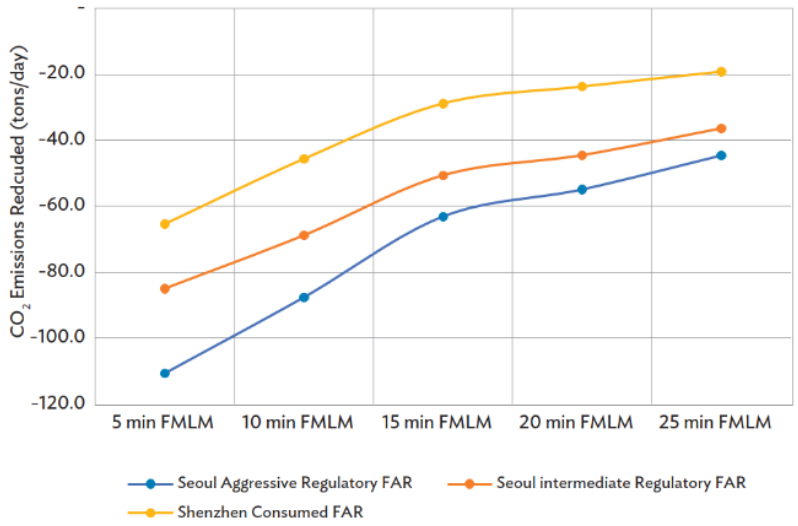
Cost-benefit analysis Framework

- **Incremental value of time (VoT) savings**
- **Incremental GHG reduction**

Scenario	Seoul intermediate regulatory FAR	Seoul aggressive regulatory FAR	Shenzhen consumed FAR
Annual time savings (million hours)	77	93	63
Annual value of time savings (2020 ₹ million)	10,002	11,927	8,008
Annual GHG Reduction (tons)	25,894	33,275	8,470

₹ = rupees, FAR = floor area ratio, GHG = greenhouse gas.

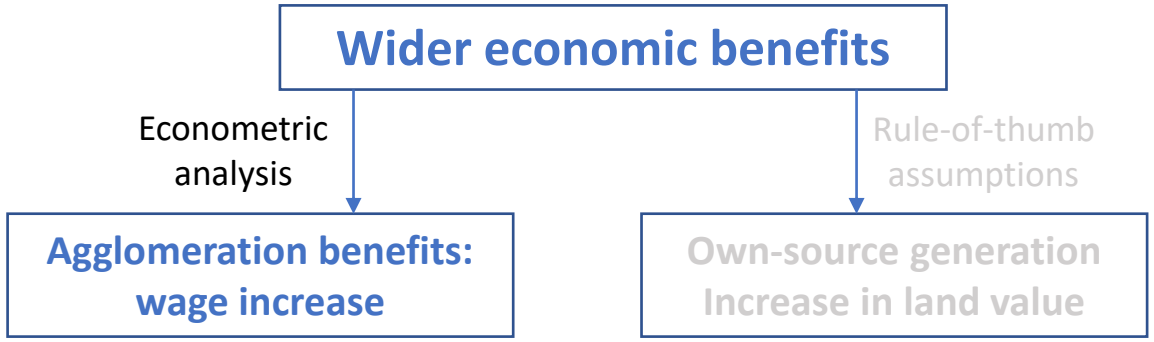




The realized gains are sensitive to first-mile-last-mile connectivity.

Source: WRI estimates.

Wider Economic Benefits



Agglomeration benefits

Theory suggests that productivity—a fundamental driver of wages—is higher in larger, denser cities.

- Workers are more likely to find jobs that are a good fit.
- Ideas and knowledge are exchanged among individuals.
- Organizations, and resources, including infrastructure, are more easily shared.

Source: Asian Development Outlook Update 2019

(i) Estimate the relationship between FAR and job density in Bengaluru

$$Job\ Density_i = \boldsymbol{\beta} * FAR\ Consumed_i + \gamma * Controls_i + \epsilon_i$$

(ii) Apply counterfactual FARs

	Seoul intermediate regulatory FAR	Seoul aggressive regulatory FAR	Shenzhen consumed FAR
Average change in job density (jobs/ square kilometer)	3,063	4,802	5,766

(iii) Apply the elasticity of wage and job density (Duranton, 2014).

Average increase in monthly wages (₹)	16,308	29,380	15,290

(iv) Distribution analysis: Wards that benefit from increased job density host over 9% of the slum population.

Note: Subscript i denote ward. The vector of controls include within metro station influence area dummy, population density; work force participation rate; share of slum population; share of population by education; travel mode share, etc.

Source: WRI estimates.

Wider Economic Benefits

Own-source generation

Changes in residential project price: around 10% (WRI, 2021)

Changes in FAR will incur increase in aggregate property value through incremental residential and commercial floor space.

The exercise accounts for: (i) increase unit cost to build high; (ii) baseline price heterogeneity across the city – inside and outside ORR; (iii) available data on land value by use; (iv) combination of FAR relaxation and metro investment.

Changes in Land Value, Property Taxes, and Profits (%)

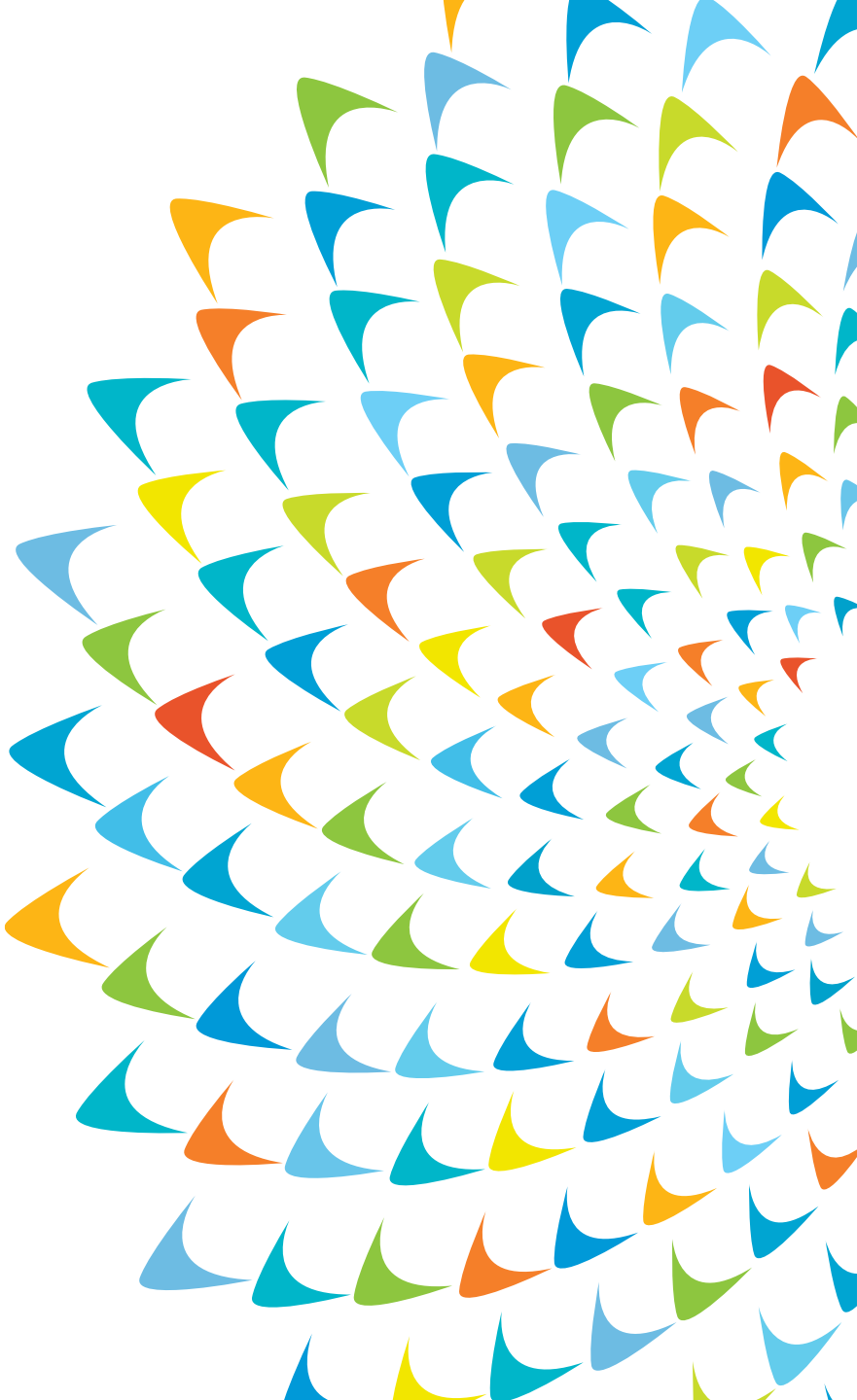
Changes to baseline	Seoul regulatory FAR	Shenzhen consumed FAR
FAR relaxation		
Property value	32	40
Property tax residential	36	39
Property tax nonresidential	51	37
Net profit	31	42
FAR relaxation + metro investment		
Property value	34	43
Property tax residential	38	41
Property tax nonresidential	55	39
Net profit	34	45

FAR = floor area ratio.

Source: WRI estimates.

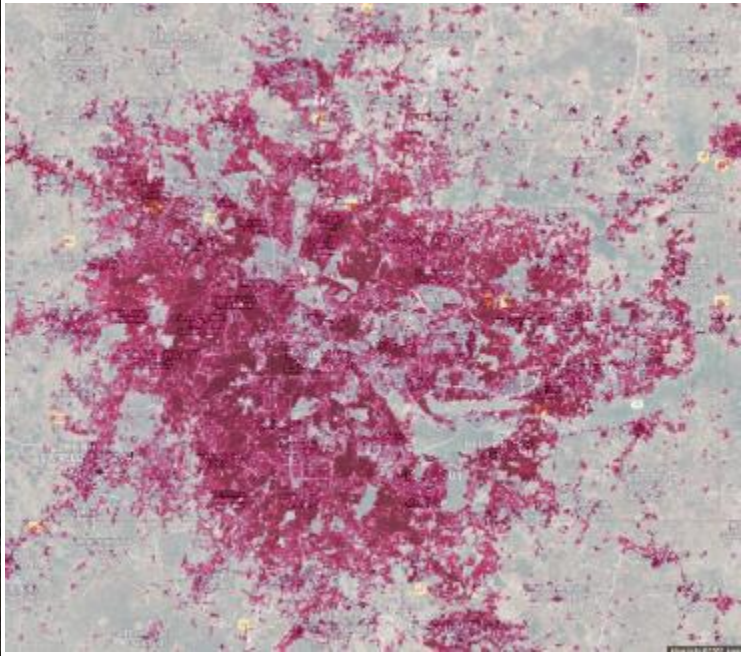
- **Main messages**
  - Remote sensing data shows that Indian cities have room for vertical growth compared to international peer cities.
  - International experiences and India's National TOD policy recommends densification, yet the implementation in India cities is uneven.
  - Implementing prescribed policies that relaxing FAR restrictions could greatly enhance the economic returns of metro investments.
- **Limitations and caveats**
  - Assumes densification automatically happens. Other limitations may emerge – e.g., utility shifting.
  - Does not account for relocation of people or firms, and therefore understates the agglomeration benefits.
  - The brown-field areas in Bengaluru may have limited scope to improve, but the study in general shows that there may be more scope to address the challenges noted for other cities.

Thank you!

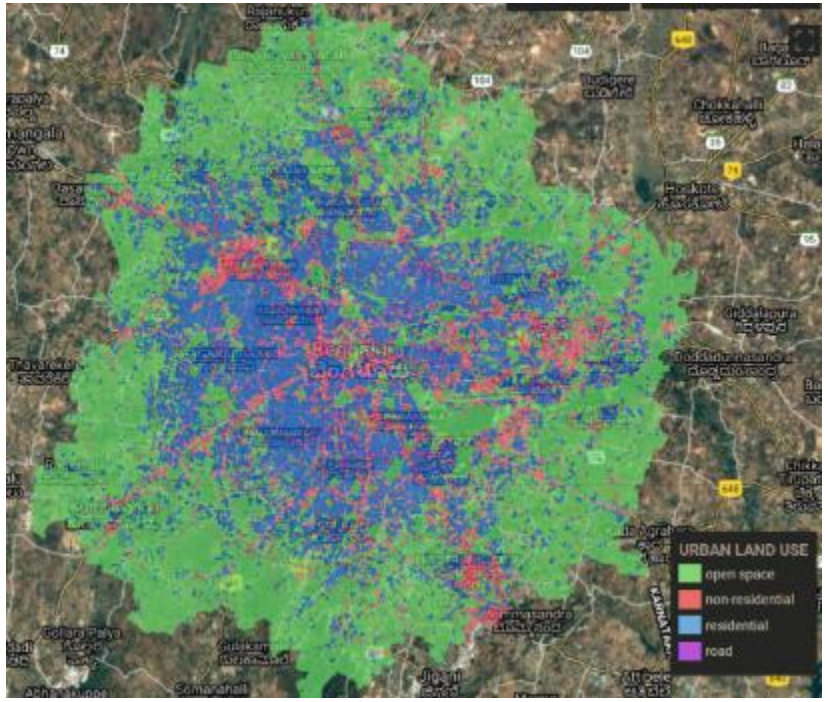


- **Additional Slides**

Building heights



Imperviousness



Urban land uses

Remote-sensing Data

Building heights - DLR WSF3D 30m (ALOS DSM)

Imperviousness - DLR WSF-imperviousness (publication in review) 30m

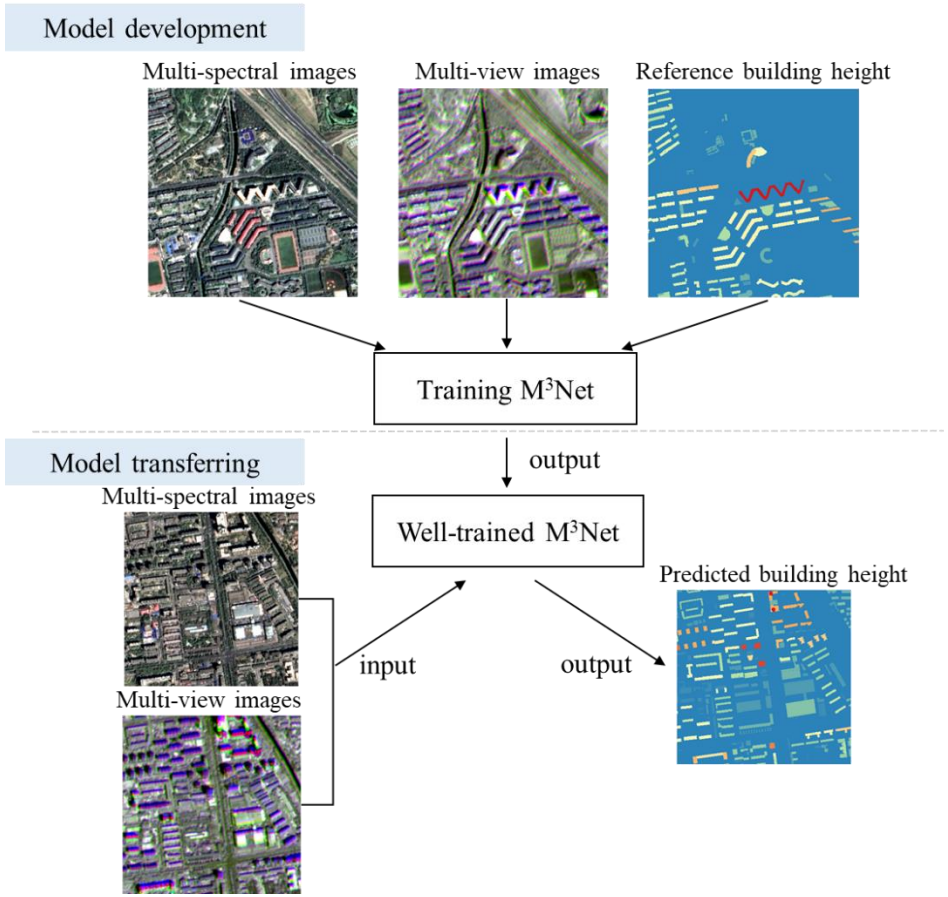
Urbanization - DLR WSF-Evolution (WSF2015) 10m

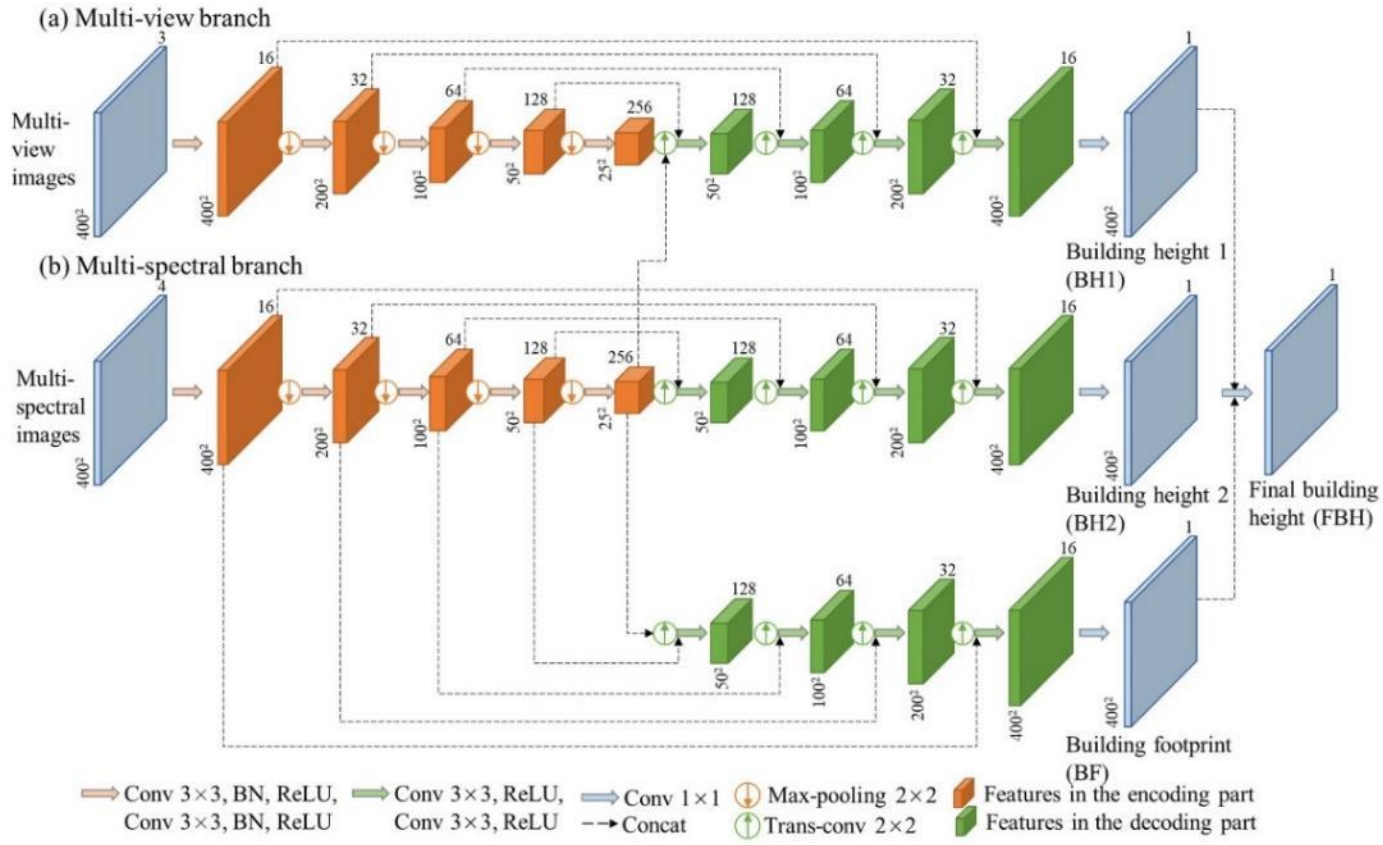
Urban land uses (Four land uses breakdown) for Bengaluru - WRI urban land use (updated publication in review)

Stations (points, buffered to 1000m radius) – municipal sources for Bengaluru and Hyderabad, OpenStreetMap (station:subway) for other cities

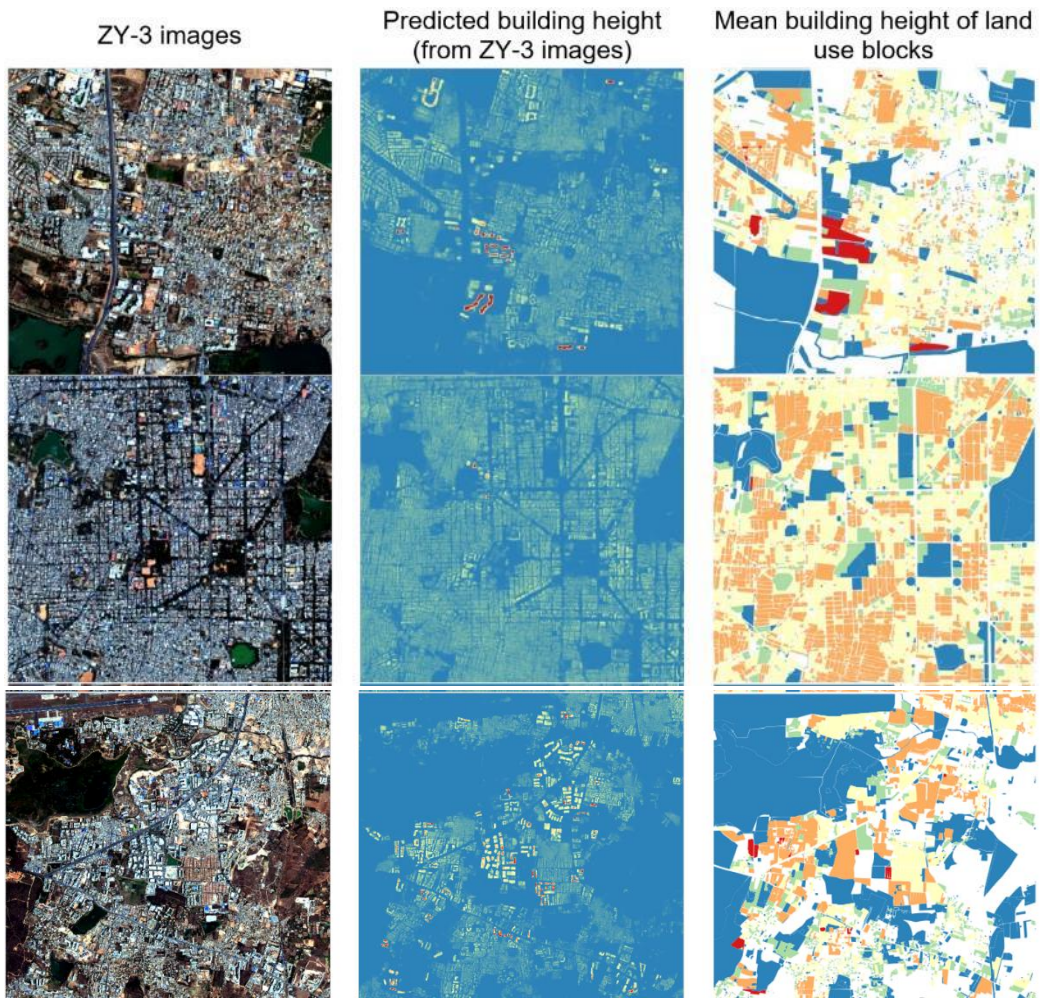
Municipal area/wards (polygons) – Municipal sources for Bengaluru and Hyderabad wards, GADM for other cities' municipal boundary

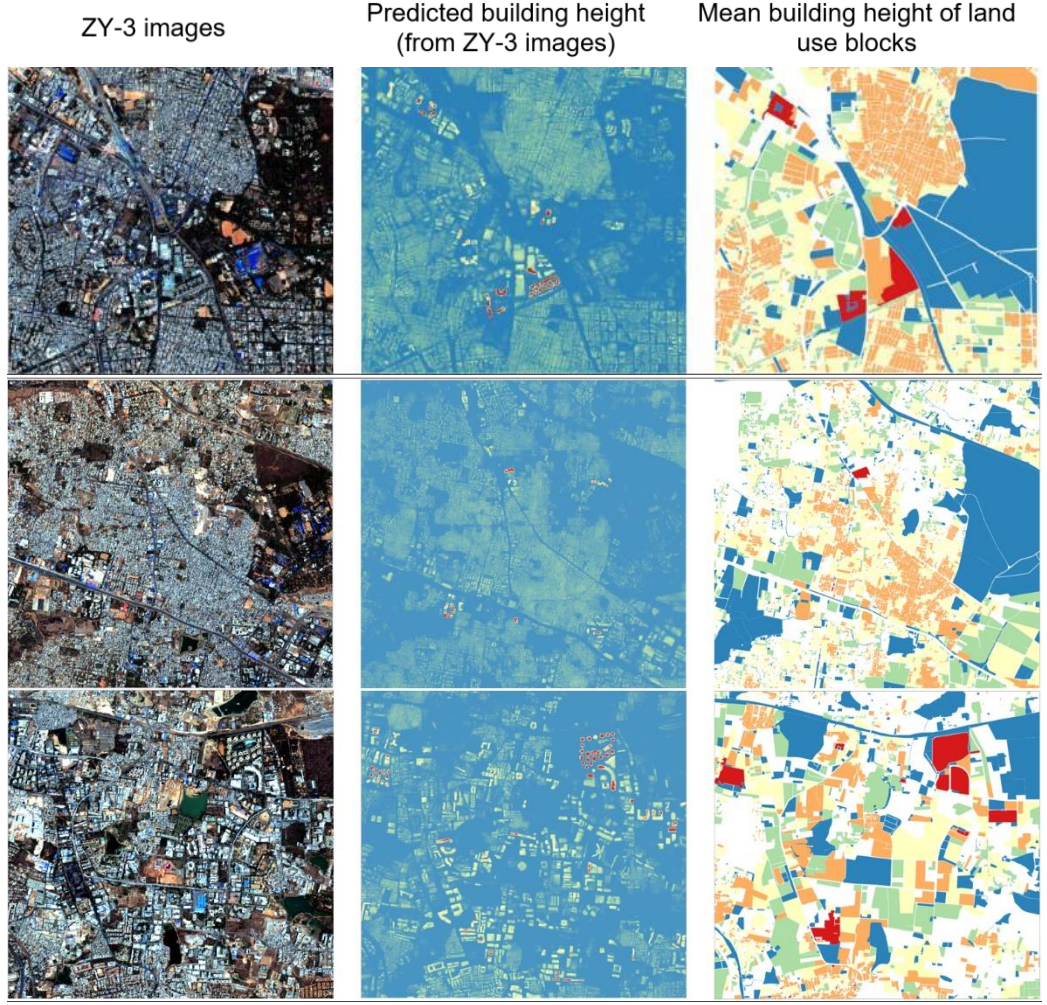
M3Net Deep learning process for building height prediction



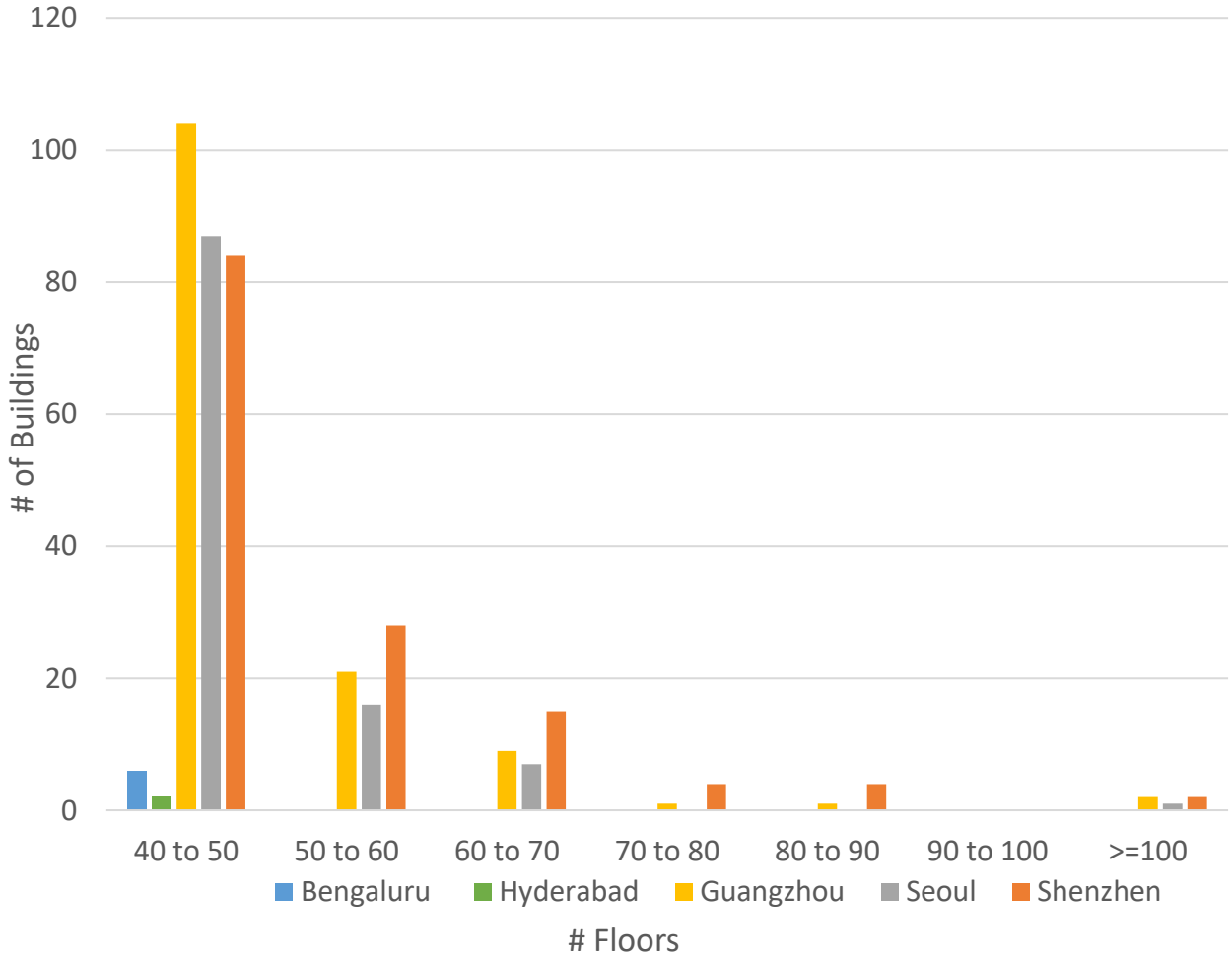


M3Net Deep learning process for building height prediction



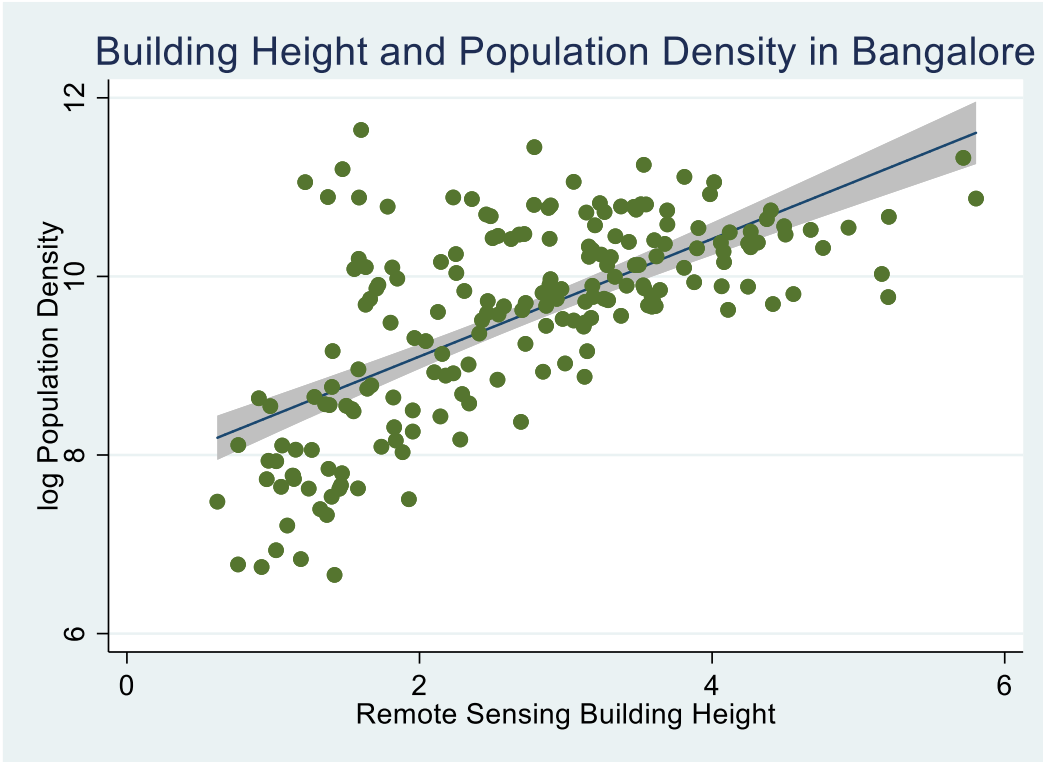


Limited vertical expansion constrains the opportunity for densification.



Number of Buildings by Building Floor Range

Source: WRI based on EMPORIS dataset



In Bengaluru, building height is positively correlated with population density at ward level

Source: ADB estimates using on DLR WSF3D 90m and Census 2011 Abstract