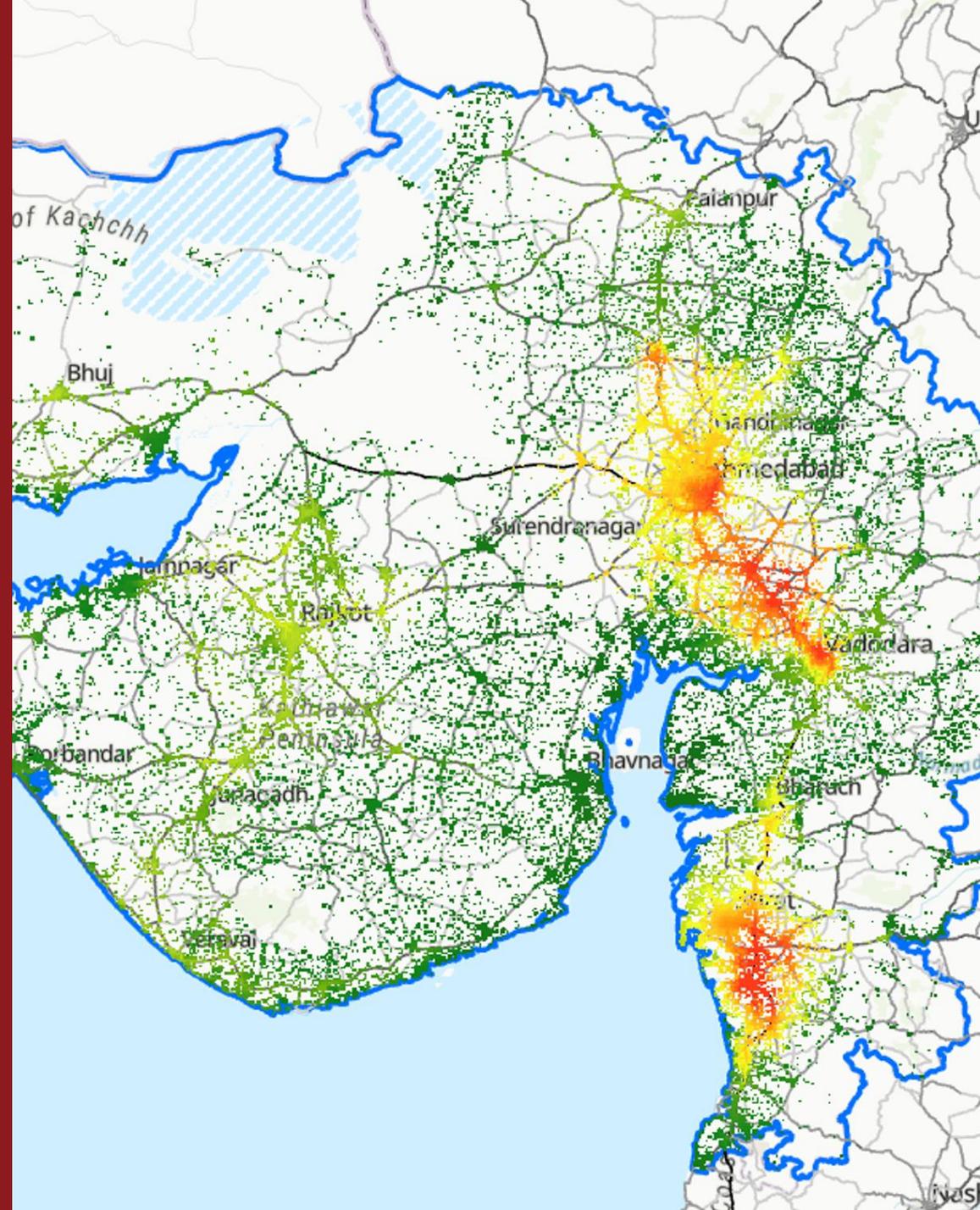# MEASURE CONNECTIVITY AND ASSESS PROJECT IMPACT

Yue Li

Spatial Economic Analysis Team

Economics Department

Asian Infrastructure Investment Bank

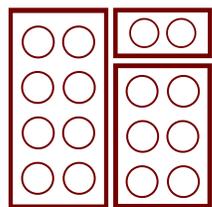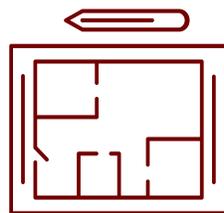March. 10, 2022
World Bank, SARCE Webinar

Motivation

Spatial Data

Road Transport Performance Across India

Impact of Gujarat Rural Road Project (MMGSY)

Team and Partnership

What we want to do

Spatial economic analysis to support investment operations
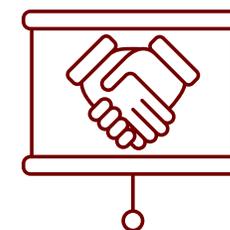
Assemble geospatial **data** related to AIIB's investment

Construct infrastructure performance **indicators** for Asian countries

Understand, and assess **impact** using economic techniques

Build **partnerships** internally and externally

3

Why start with connectivity

A significant sector for development financing

A thematic priority for AIIB

Improve infrastructure connectivity to foster sustainable economic development

- Where: country, region, inter-city, intra-city, rural, border region
- How: road, metros, railway, bridges, airports; electronic vehicles; logistics services
- Potential impacts: efficiency, inclusion, sustainability

October 15, 2020
Lao PDR: Climate Resilience Improvement of National Road 13 South Project (Section 3)

April 3, 2020
Bangladesh: Sylhet to Tamabil Road Upgrade Project

December 21, 2016
Azerbaijan: Trans Anatolian Natural Gas Pipeline Project (TANAP)

June 24, 2016
Pakistan: National Motorway M-4 (Shorkot-Khanewal Section)

How to measure connectivity

European Commission methodology

For any populated cell (1 km X 1 km)

- **Proximity**: Number of people within a buffer area.
- **Accessibility**: Number of people within a service area using a road network.
- **Transport Performance**: **Ratio between accessibility and proximity.**

Transport Performance

$$\frac{Accessibility}{Proximity} * 100\%$$
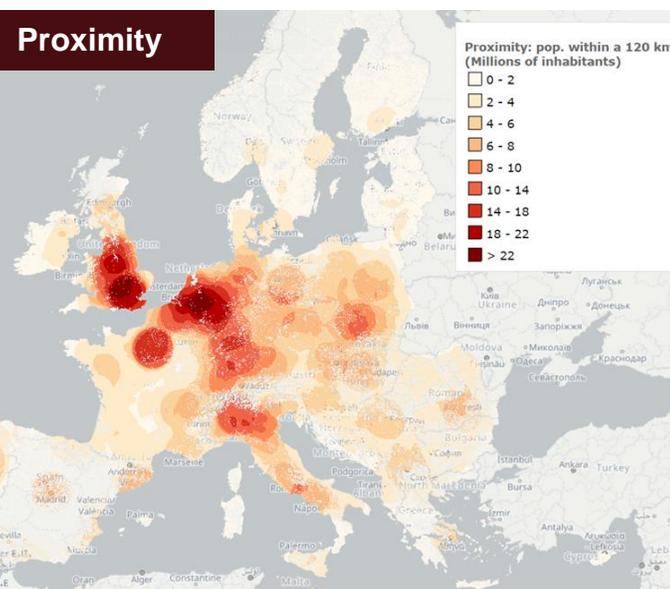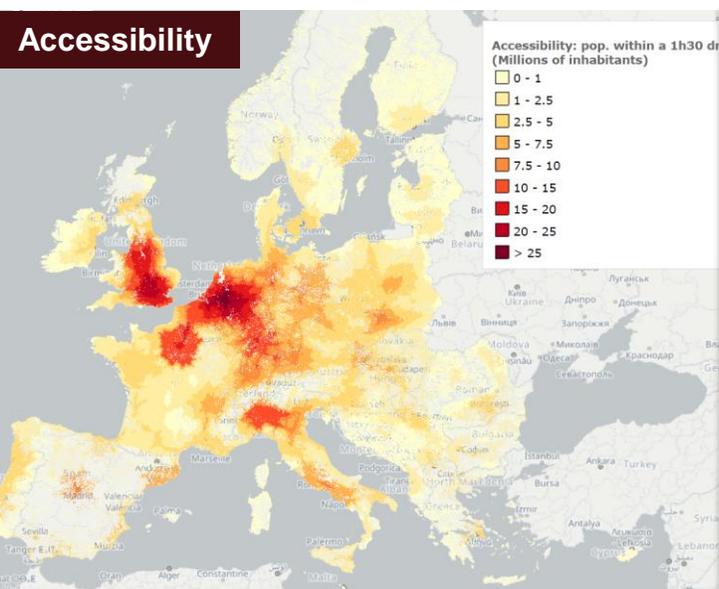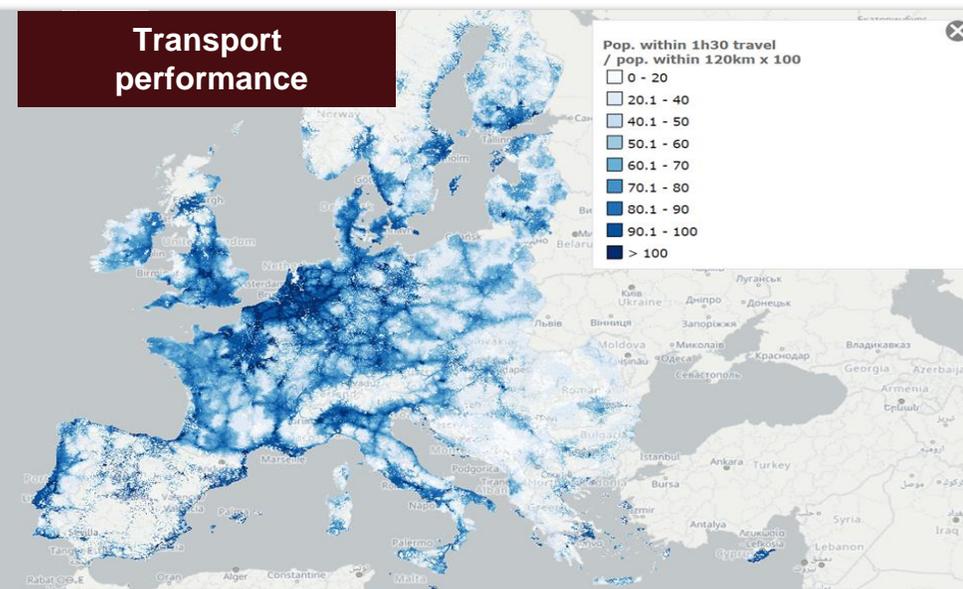
How to assess impact of improved connectivity

Road rehabilitation in Haiti

Using nighttime lights data and comparing treated and control areas (Mitnik et al. 2018)

Receiving a road rehabilitation project leads to a 0.5-2.1% increase in communal section GDP.

Road improvement and nighttime light, 2000
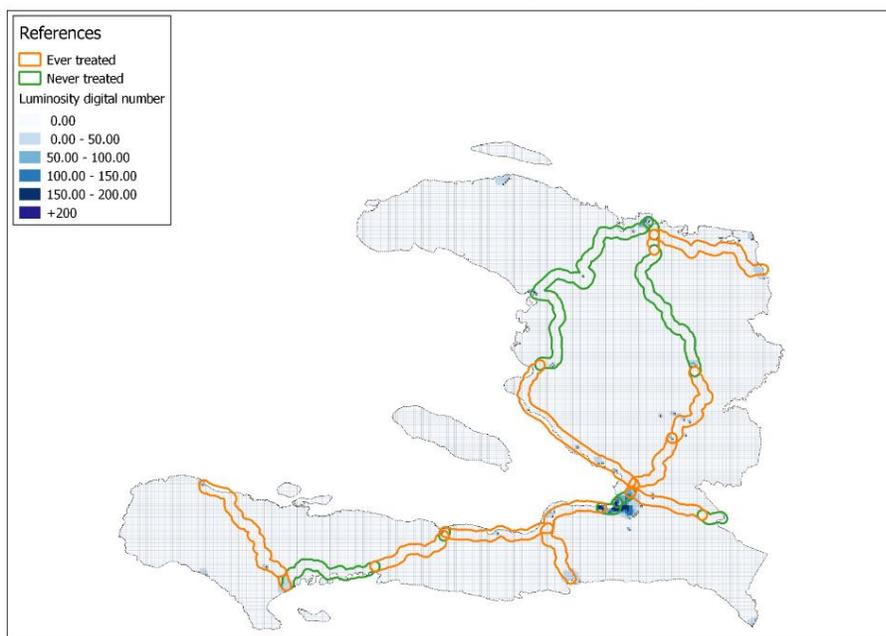
Road improvement and nighttime light, 2013
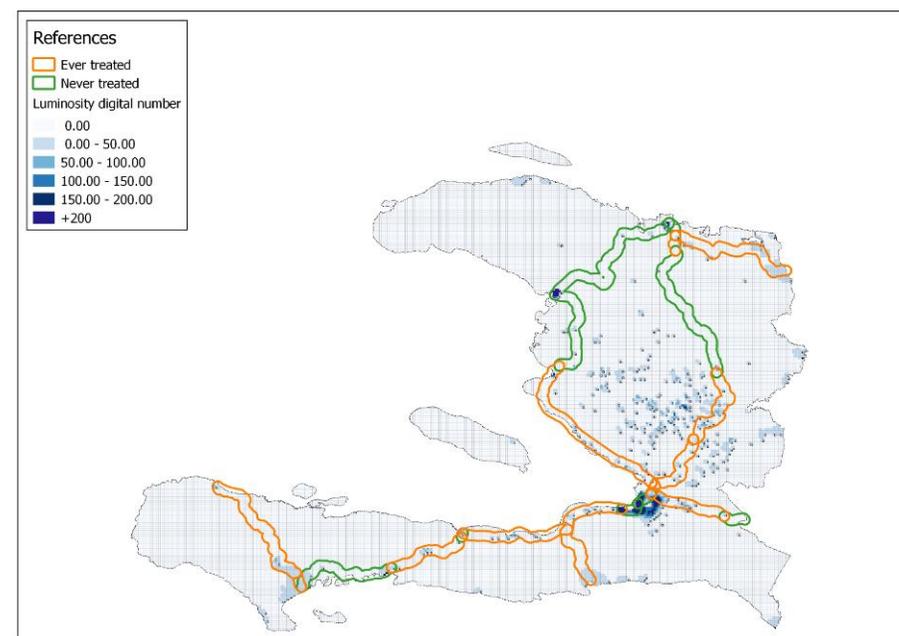
What we find

- **Road transport performance across India:**
  - India's performance trails behind most European countries (28% v.s. 71%).
  - Among major states, Maharashtra and Gujarat show reasonable records (>=40%) whereas Bihar and Uttar Pradesh fall far behind their potentials (<= 25%).
  - Mumbai and Delhi are on par with European urban areas (66%, 79%).
  - Rural areas of Haryana, Gujarat, Kerela, Tamil Nadu and Punjab, outperform urban areas of other states.

- **Impact of Gujarat rural road project (MMGSY):**
  - Simulation on transport performance: 4 percentage point increase in project villages.
  - Estimation on local output: 0.5-2% increase in treated villages relative to controls.
  - Estimation on local employment/MNREGA: a significant increase in treated areas relative to controls.

Motivation

Spatial Data

Road Transport Performance Across India

Impact of Gujarat Rural Road Project (MMGSY)

Team and Partnership

Modern spatial data

- **Build road networks from commercial GIS-based road information**
  - Consider multiple factors at once
  - Compare with official statistics and google map-based travel information

- **Select gridded population data across open sources**
  - Visual and statistical comparison between data sources
  - Compare with official statistics

- **Clean satellite image-based nighttime lights data**

- **Integrate data on land use pattern, terrain, climate characteristics, etc**
  - Tap into World Bank South Asia Spatial Database

Traditional spatial data

- **Administrative Atlas**
  - World Bank South Asia Spatial Database
  - Digitized boundaries of administrative units
  - States, districts, subdistricts, and cities/towns/villages

- **Population and Housing Census**
  - World Bank South Asia Spatial Database
  - Spatial identifier: states, districts, subdistricts, cities/towns/villages
  - Matched with administrative boundaries through fuzzy matching

- **Rural Employment Data**
  - Work demanded, work allotted, person-days under the Mahatma Gandhi Rural Employment Scheme (MNREGA)
  - Spatial identifier: census blocks, matched with village information

- **Agricultural Production Market Data**
  - Quantity arrivals and prices at the markets
  - Spatial identifier: pincodes, matched with village information

Motivation

Spatial Data

Road Transport Performance Across India

Impact of Gujarat Rural Road Project (MMGSY)

Team and Partnership

Road transport performance measure: Concept

Higher connectivity = More people can be reached within the normal commuting time

- **Proximity**: within 90 minutes time, assume that one can drive at 80km/hour in a straight line, how many people can one reach in this *ideal* case? (80km/hour X 1.5 hr = 120 km)

- **Accessibility**: within a 90 minutes drive, how many people can one reach using existing road network *in reality*?

120km

90min drive area

Road Transport Performance

$$\frac{Accessibility}{Proximity} * 100\%$$
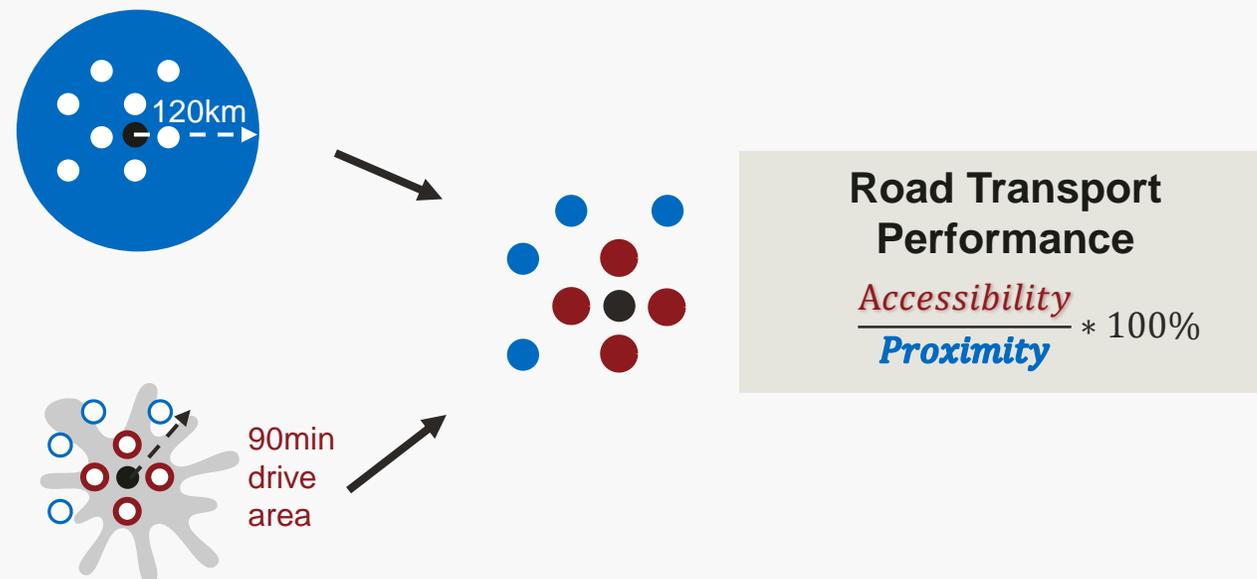
Road transport performance measure: Computation

Data:

A high-resolution population grid

A detailed transportation network

Define buffer, service areas

Unit of analysis:

1 sq km populated cells.

Buffer are for <u>proximity</u>:

120 km radius without network use.

Service area for <u>accessibility</u>:

90 minutes drive by car, based on the road network built for India.

Number of inhabitants within each area are calculated and used to compute the corresponding indicators.
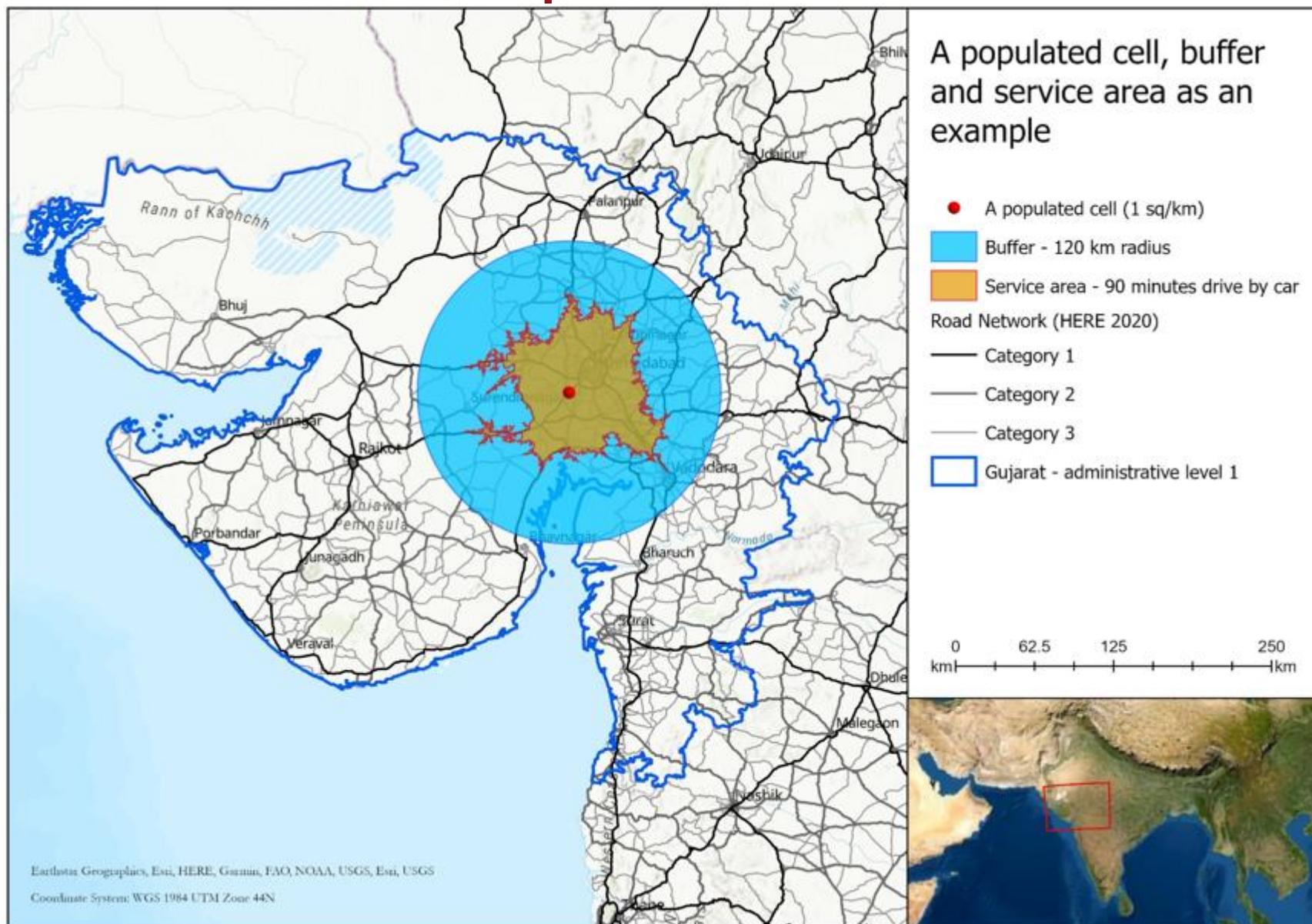
A populated cell, buffer and service area as an example

- ● A populated cell (1 sq/km)
- ▇ Buffer - 120 km radius
- ▇ Service area - 90 minutes drive by car

Road Network (HERE 2020)

— Category 1
— Category 2
— Category 3
▢ Gujarat - administrative level 1

Earthstar Geographics, Esri, HERE, Garmin, FAO, NOAA, USGS, Esri, USGS

Coordinate System: WGS 1984 UTM Zone 44N

The maps and the national boundaries are used to illustrate the results of the analysis. They do not represent the view of AIIB, the view of its Board of Directors and the view of its staff on internationally disputed territories.

Proximity indicator in India

Population within a 120 km radius
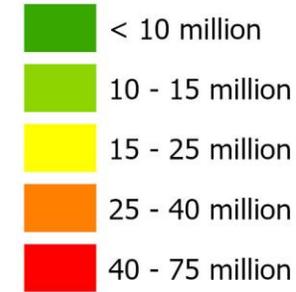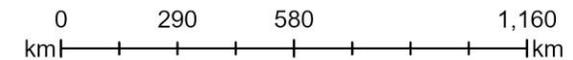
- < 10 million
- 10 - 15 million
- 15 - 25 million
- 25 - 40 million
- 40 - 75 million

Based on GHSL population 2015; HERE 2020

0   290   580   1,160
km   km

Esri, GEBCO, DeLorme, NaturalVue, Earthstar Geographics

Coordinate System: WGS 1984 UTM Zone 44N

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Accessibility indicator in India

Population within a 90 minutes drive by car
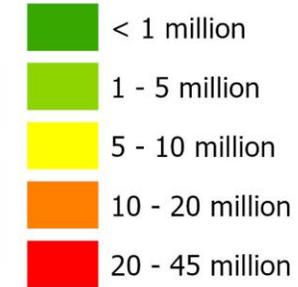
- < 1 million
- 1 - 5 million
- 5 - 10 million
- 10 - 20 million
- 20 - 45 million

Based on GHSL population 2015; HERE 2020

| 0 | 290 | 580 | 1,160 |

km ⊢—————————————⊣ km

Esri, GEBCO, DeLorme, NaturalVue, Earthstar Geographics

Coordinate System: WGS 1984 UTM Zone 44N

15

The maps and the national boundaries are used to illustrate the results of the analysis. They do not represent the view of AIIB, the view of its Board of Directors and the view of its staff on internationally disputed territories.

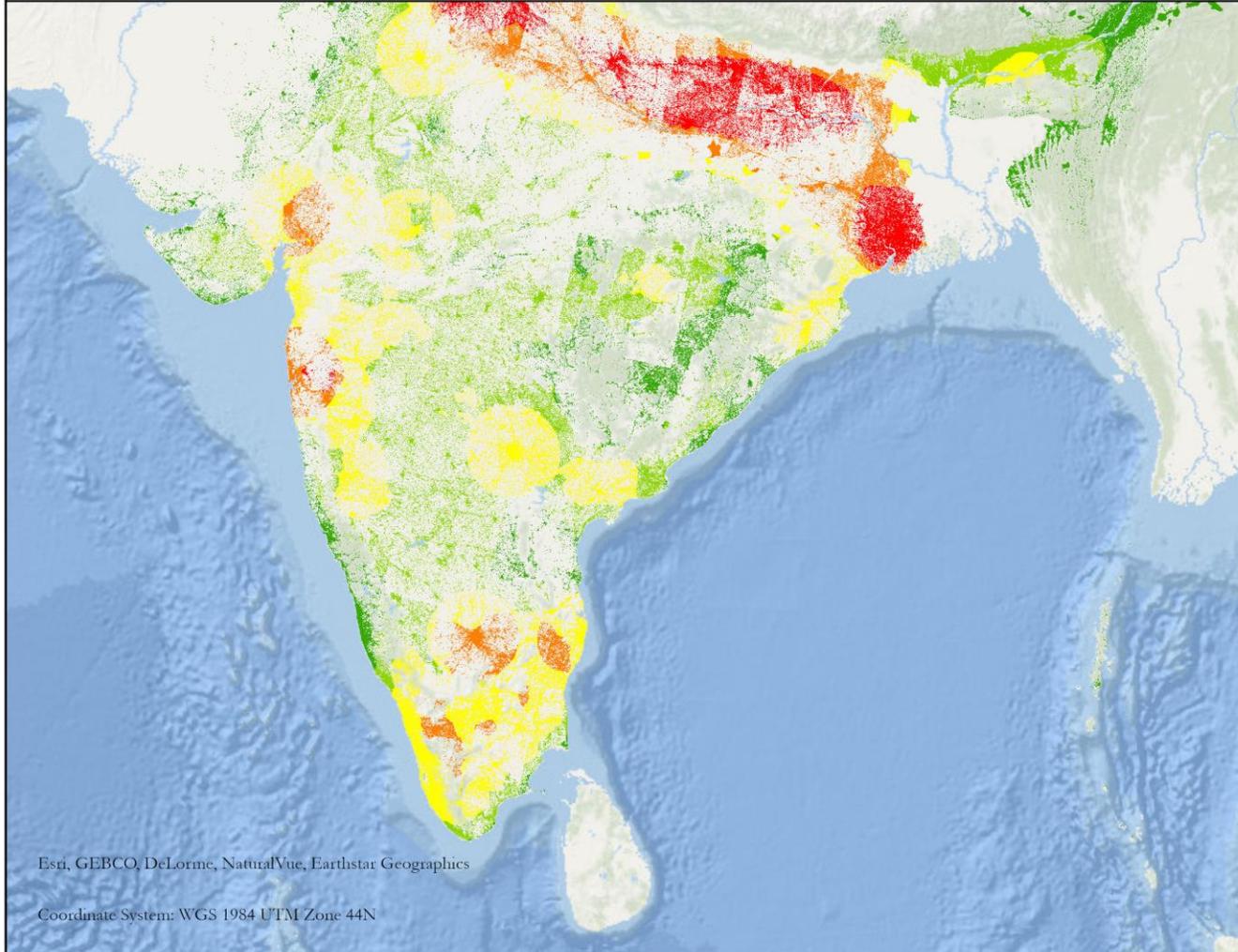Transport performance indicator in India, per square kilometer

Trans. Perf. (Accessibility / Proximity * 100)

- < 10%
- 10% - 20%
- 20% - 30%
- 30% - 40%
- 40% - 50%
- 50% - 60%
- 60% - 70%
- 70% - 100%

Based on GHSL population 2015; HERE 2020

0   290   580   1,160
km⊢   ⊣km

Esri, GEBCO, DeLorme, NaturalVue, Earthstar Geographics

Coordinate System: WGS 1984 UTM Zone 44N

16
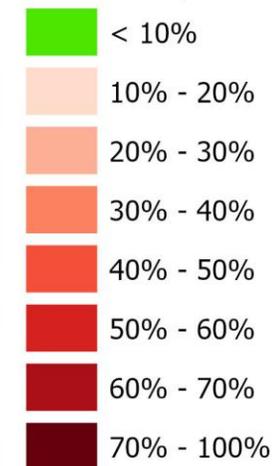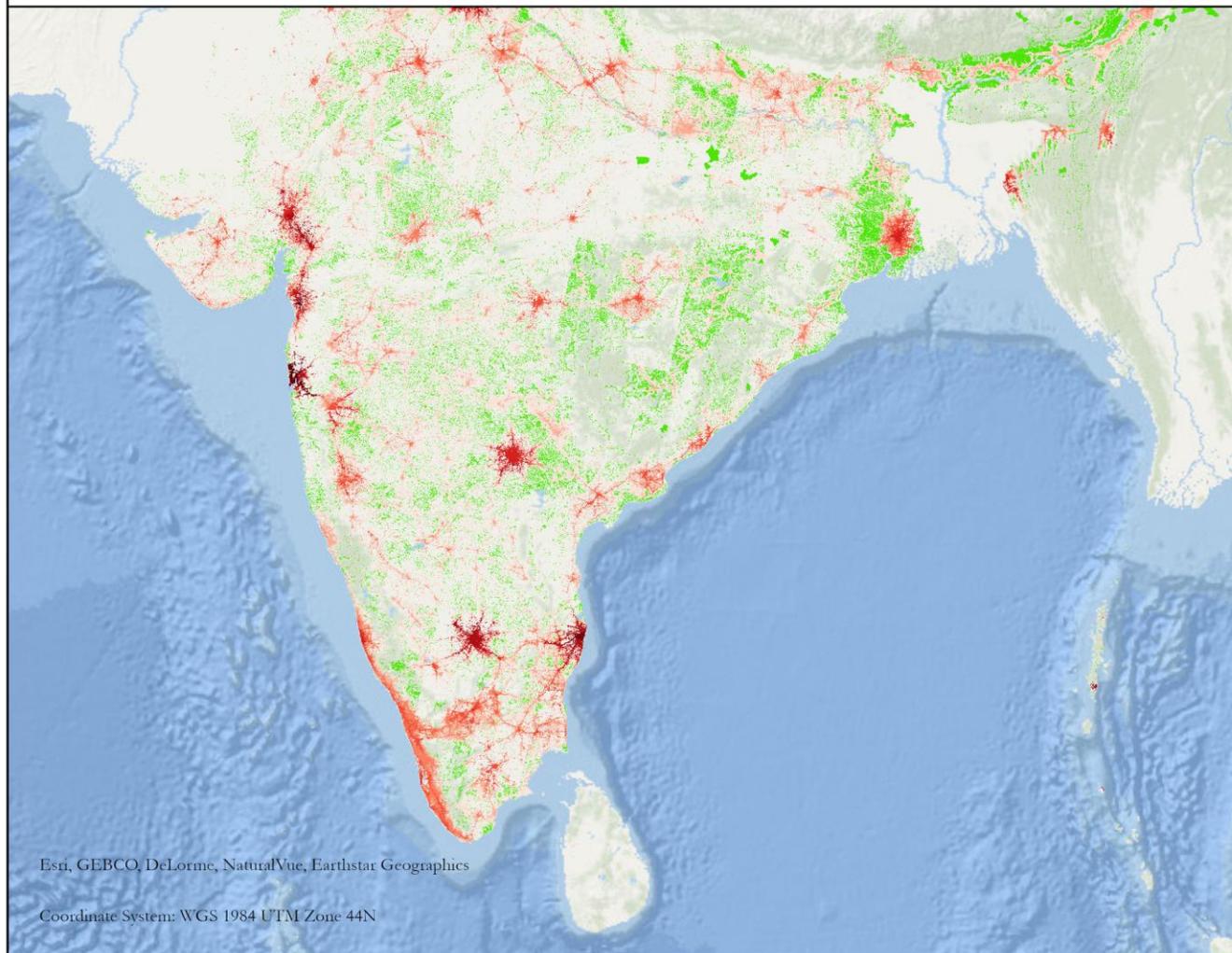
India's performance falls far behind most European countries, but performance varies significantly across major states

STATE	POPULATION (mil. People)	POPULATION DENSITY (peop/km^2)	PROXIMITY (mil. people)	ACCESSIBILITY (mil. people)	TRANSPORT PERFORMANCE (%)
NCT of Delhi	18	12059	61	41	66
Maharashtra	121	392	20	8	41
Gujarat	66	350	18	7	40
Haryana	28	625	43	17	39
Karnataka	65	339	17	6	37
Tamil Nadu	76	586	21	8	36
Kerala	33	874	19	7	36
Punjab	30	595	22	7	31
Telangana	38	328	17	5	29
Uttar Pradesh	217	902	42	10	25
West Bengal	98	1132	41	10	25
Andhra Pradesh	52	324	13	3	22
Bihar	117	1231	50	10	20
Rajasthan	76	220	15	3	20
Chhattisgarh	28	204	12	2	20
Madhya Pradesh	78	253	14	2	18
Jharkhand	37	454	26	4	16
Assam	35	426	12	2	15
Odisha	45	290	13	2	13
India (all)	1311	412	26.9	7.4	28

Europe's Transport Performance

Mean	73
Max	110
Min	20

Rural areas of Haryana, Gujarat, Kerela, Tamil Nadu and Punjab, outperform urban areas of other states, such as Bihar and Madhya Pradesh.

Europe Transport Performance	Min	Max	Average
Rural	20.3	96.3	63.9
Towns and suburbs	25.4	102.5	71.9
Cities	33.4	110.4	83.0

Transport Performance, by the level of urbanization (%) (y-axis)

States (x-axis): INDIA, Assam, Jharkhand, Odisha, Madhya Pradesh, Bihar, Rajasthan, Uttar Pradesh, Chhattisgarh, Andhra Pradesh, West Bengal, Kerala, Punjab, Chandigarh, Telangana, Tamil Nadu, Gujarat, Karnataka, Haryana, Maharashtra, NCT of Delhi

Legend: ● Rural areas ● Towns and suburbs ● Cities

Note: Bubble areas represent the share of population within the states

Mumbai and Delhi are on par with European urban areas but majority of the over 2000 sub-districts register poor performance
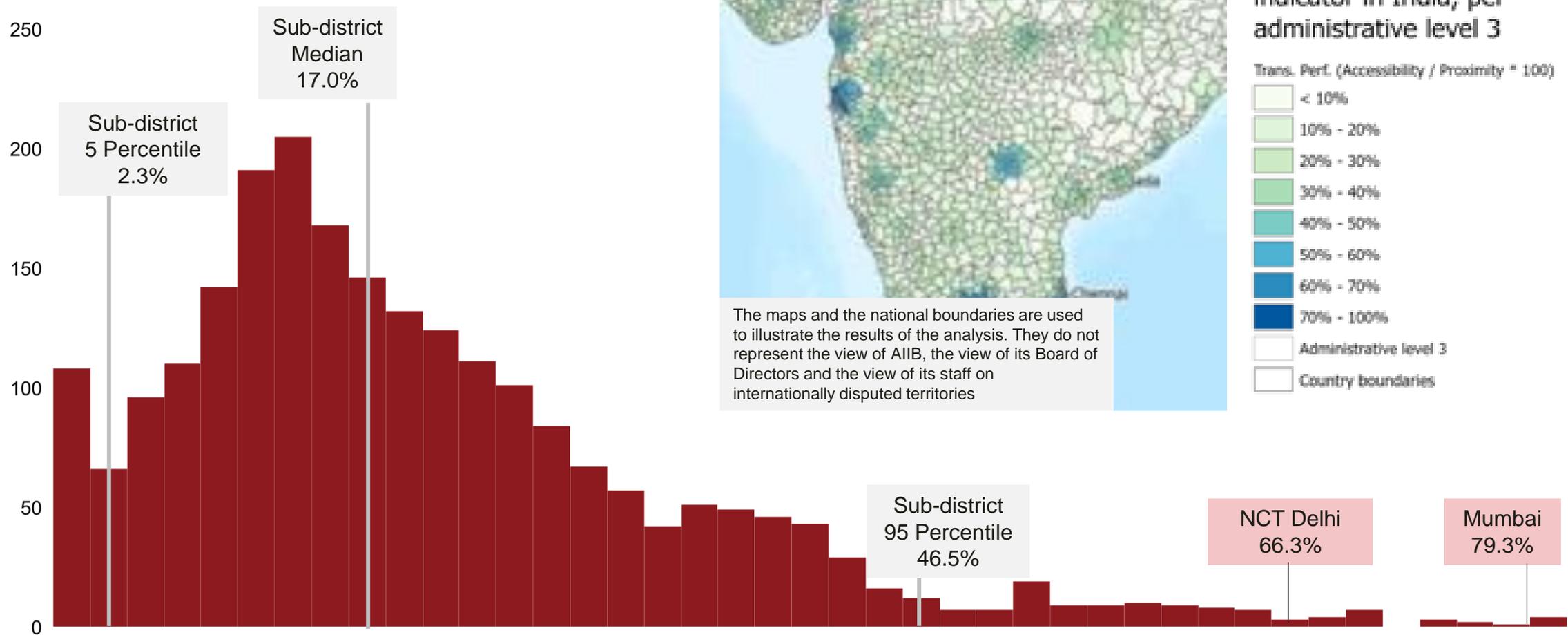
Sub-district Median 17.0%

Sub-district 5 Percentile 2.3%

Sub-district 95 Percentile 46.5%

NCT Delhi 66.3%

Mumbai 79.3%

Transport performance indicator in India, per administrative level 3

Trans. Perf. (Accessibility / Proximity * 100)

- < 10%
- 10% - 20%
- 20% - 30%
- 30% - 40%
- 40% - 50%
- 50% - 60%
- 60% - 70%
- 70% - 100%
- Administrative level 3
- Country boundaries

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Distribution of sub-district transport performance divided in 50 equal width bins, with each bin width as 2 percent

Public expenditure increases road length but not always performance

Road length vs. Stock of expenditure

Data source: Reserve Bank of India, CEIC, HERE and AIIB staffs' calculation

Performance vs. Stock of expenditure

Data source: Reserve Bank of India, CEIC, HERE and AIIB staffs' calculation
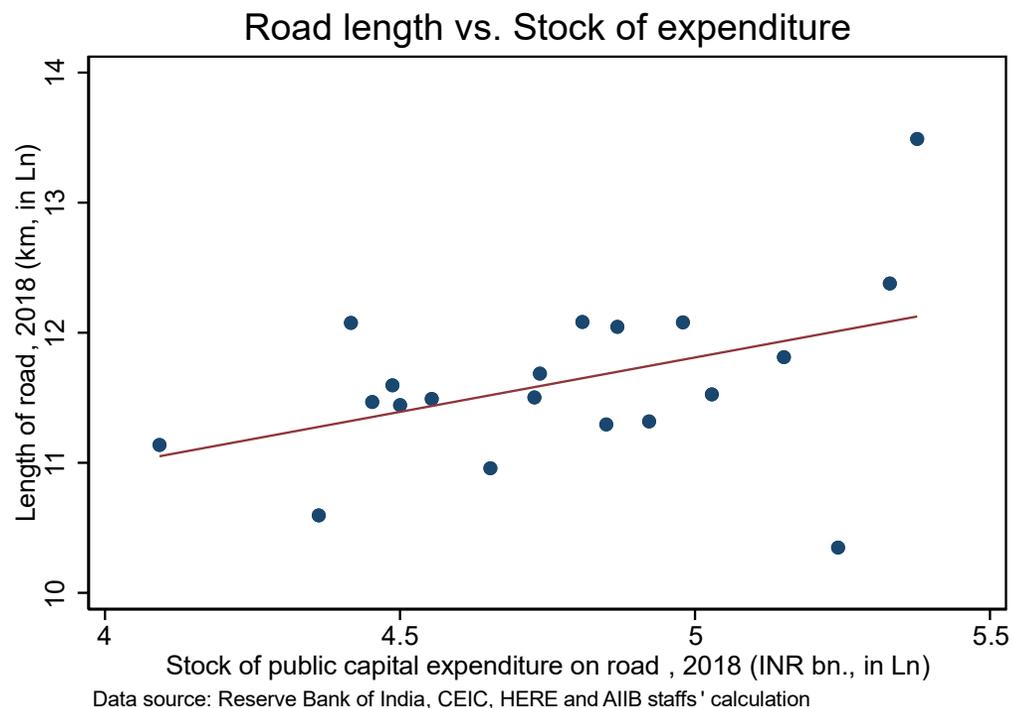
- **Positive and significant** correlation
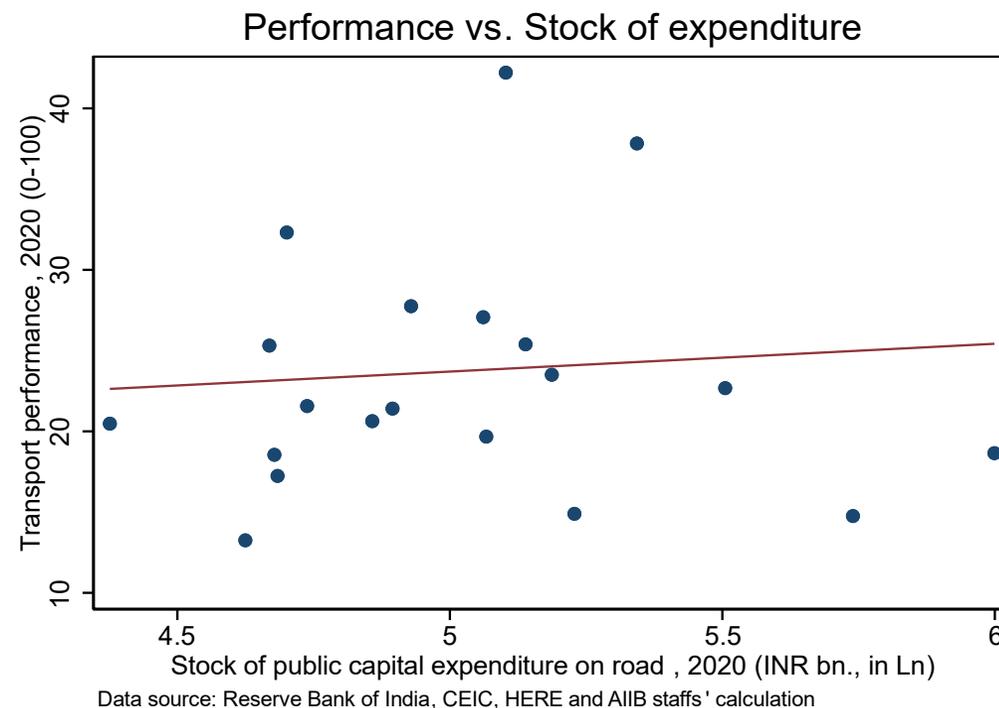
- **Insignificant** albeit positive correlation

Note: The analysis for both figures control for GDP, population, land characters and climate variations across states

Road transport performance measure: Discussion

Advantages of this methodology:
- High granularity.
- Not biased by settlement size, suitable for territorial analysis at any scale.
- Useful for identifying strengths and weaknesses of a transport system spatially.
- Measuring efficiency/quality of investment.
- Accessibility resembles "market access" concept.

Shortcomings of this methodology:
- Population gridding may use infrastructure data to spread census population numbers beyond the centroids of administrative units.
- Not considering congestion.

Application:
- Simulating the impact of road investments

Future extensions:
- Access to jobs and services
- Performance of other transport investments

- **Motivation**

- **Spatial Data**

- **Road Transport Performance Across India**

- **Impact of Gujarat Rural Road Project (MMGSY)**

- **Team and Partnership**

India Prime Minister's rural road project (PMGSY)

Objective and scope

- Improve road transport connectivity.
- Rural roads to all villages with more than 500 people.
- Started in 2000 and continues in some states.
- By 2015, over 400,000 km of rural roads, costing USD40 billion, benefiting 185,000 villages.
- By 2014, 99.6% of the project roads were completed in Gujarat.

Debate about its cost-effectiveness

The last mile connectivity can be instrumental in

- Integrating local economies with external markets,
- Facilitating technological adoption in agriculture production, Stimulating mobility and non-farm activities.

But

- These remote areas face other obstacles.
- Need to address the issue of accessing to "what".

Evidence

- Aggarwal (2018):
  - Lower prices and increased availability of non-local goods.
  - Increased use of agricultural technologies.

- Asher and Novosad (2020):
  - **No major changes** in agriculture outcomes, income, or assets.
  - **Slight expansion of employment** in local firms.
  - **Improved connection of rural works** to new employment opportunities outside.

Gujarat Chief Minister's rural road project (MMGSY)

Objective and scope
- Improve road transport connectivity
- Provide all weather rural roads to villages with fewer than 500 people.
- Project time, Phase 1: 2016-2019.
- Coverage, Phase 1: 13,582 km of rural roads,
- Cost, Phase 1: USD403 million, AIIB financed 81.6% of the project cost (USD329 million).

Expected impact
- Increased agricultural productivity and industrial development.
- New employment opportunities.
- Higher non-farm employment opportunities and increased rural income.
- Changes in travel patterns, modes from bullock carts to motorized transport.
- Reduced travel time and better access to hospitals and schools, and other services.

Impact of Gujarat rural road project: Identification of treated areas

Treated villages:

- Identify villages with fewer than 500 people according to the 2011 Census.

- Match with the Administrative Atlas of India.

	Count	Share
Treated villages (<500 people)	2867	13%
Control villages (500-1000 people)	3889	17%
Control villages (>1000 people)	15358	68%
Urban areas	503	2%
Total adm. units	22617	100%

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Rural road simulation in Gujarat, India - Settlement categories

Settlement Categories
- Treated villages (< 500 inhabitants)
- Non-treated villages I (500 - 1000 inhabitants)
- Non-treated villages II (> 1000 inhabitants)
- Urban areas
- Gujarat - administrative level 1

Earthstar Geographics, Esri, HERE, Garmin, FAO, NOAA, USGS, Esri, USGS

Coordinate System: WGS 1984 UTM Zone 44N

Simulate impact of Gujarat rural road project on transport performance: Methodology

How would transport performance change in treated villages if roads connected to them were downgraded?

Methodology:

- Overlay road network with digitized Administrative Atlas

- Identify all roads passing treated villages

- Downgrade speed category of the lower-grade roads by one level

- Exclude motorways and highways

- Compute transport performance

- Compare results before/after the simulation

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Scenario simulation in Gujarat, India - rural roads downgrading in time t-1: selected rural roads

Road Network (HERE 2020)
— Category 1
— Category 2
— Category 3
— Other road categories
■ Selected villages for simulation
— Selected rural roads for simulation
☐ Gujarat - administrative level 1

0   62.5   125   250
km├────┼────┼────┤km

Esribase Geographies, Esri, HERE, Garmin, FAO, NOAA, USGS, Esri, USGS
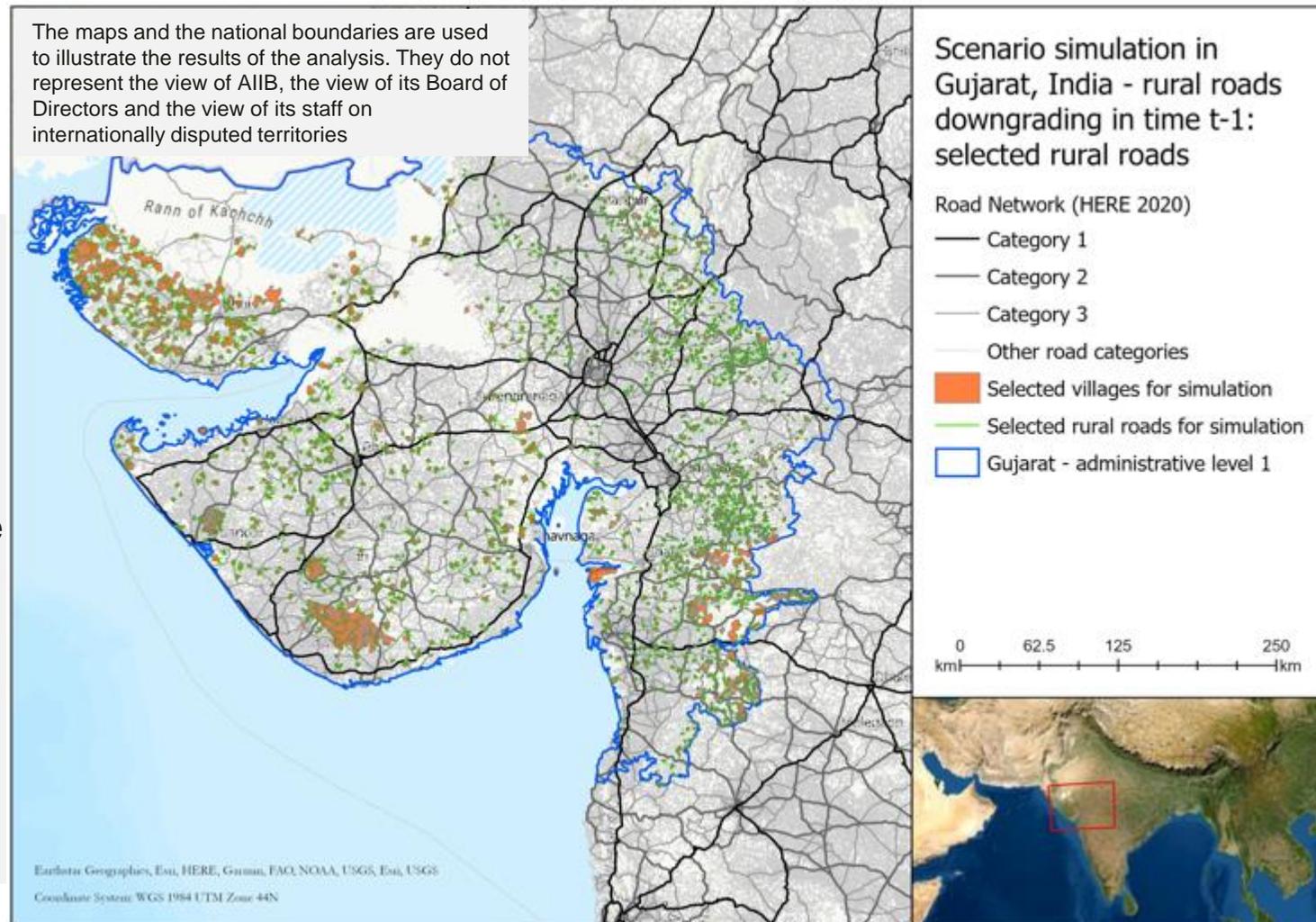Coordinate System: WGS 1984 UTM Zone 44N

Simulate impact of Gujarat rural road project on transport performance: Methodology

How would transport performance change in treated villages if roads connected to them were downgraded?

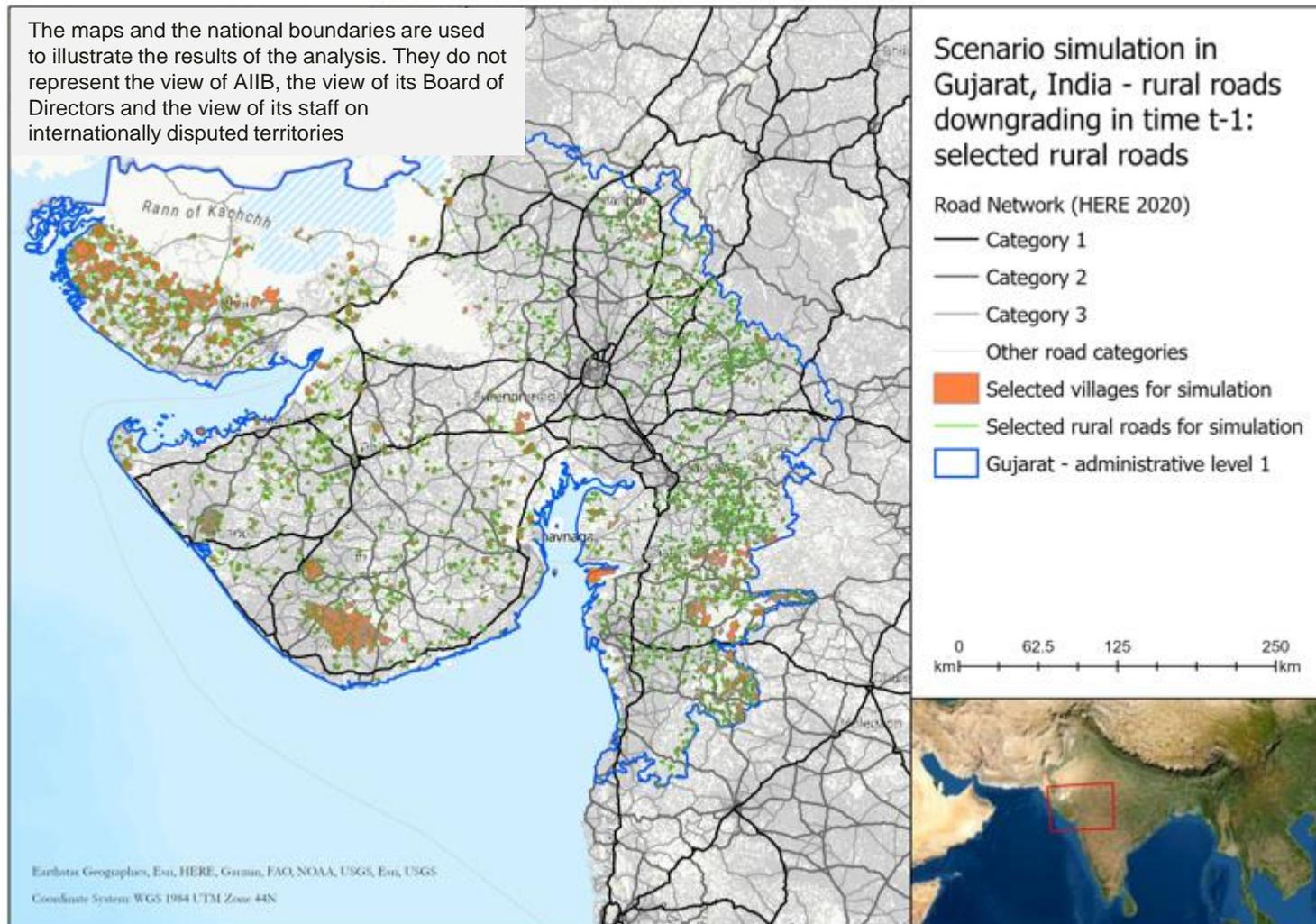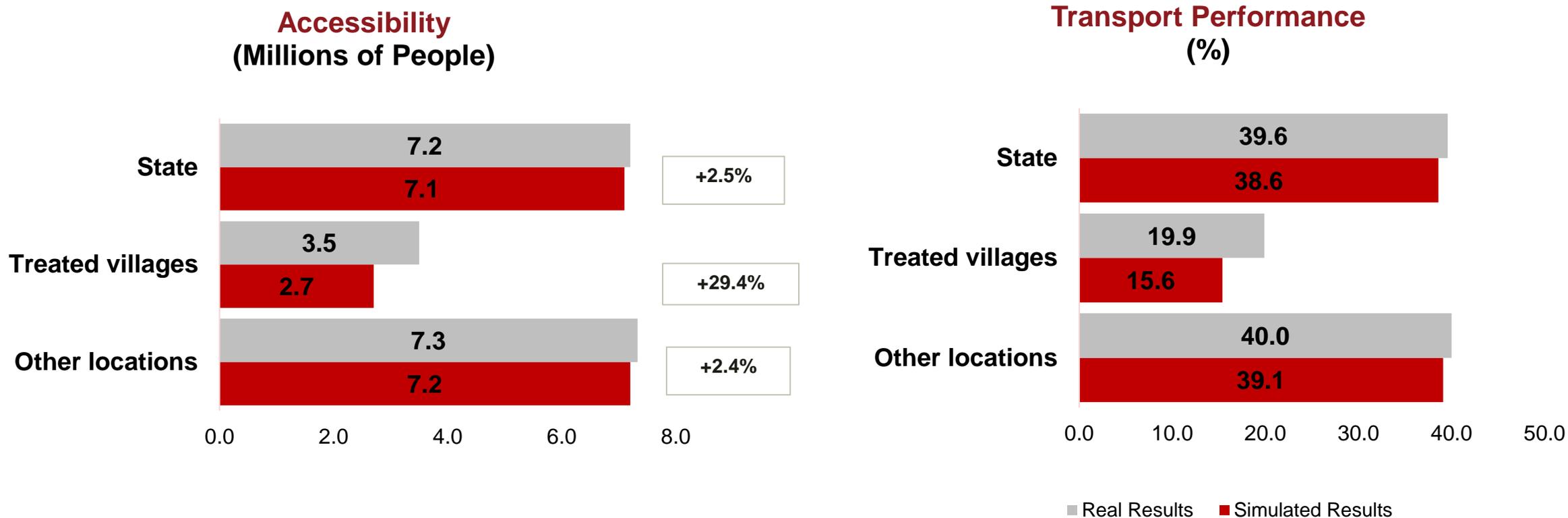| Speed downgrade	Length (km)	Share
From 91 unchanged	25	0.1%
From 71 unchanged	260	1.3%
From 51 to 31 kmph	344	1.7%
From 31 to 11 kmph	2033	10.0%
From 11 to 5 kmph	17683	86.9%
Total	20345	100.0%

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Scenario simulation in Gujarat, India - rural roads downgrading in time t-1: selected rural roads

Road Network (HERE 2020)
— Category 1
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Selected villages for simulation
Selected rural roads for simulation
Gujarat - administrative level 1

0   62.5   125   250 km

Earthstar Geographics, Esri, HERE, Garmin, FAO, NOAA, USGS, Esri, USGS
Coordinate System: WGS 1984 UTM Zone 44N

Simulate impact of Gujarat rural road project on transport performance: Results

Accessibility
(Millions of People)

State	7.2 / 7.1	+2.5%
Treated villages	3.5 / 2.7	+29.4%
Other locations	7.3 / 7.2	+2.4%

Transport Performance
(%)

State	39.6 / 38.6
Treated villages	19.9 / 15.6
Other locations	40.0 / 39.1

■ Real Results   ■ Simulated Results

Estimate impact of Gujarat rural road project on economic activities: Methodology

Impact assessment of MMGSY

- Follow the two-way fixed effects Difference-in-Differences estimation approach.

- Assess the differences between the average performance of

    - the identified treated areas and the control areas

    - in years after the project (2017 onwards) relative to the years before (2016 and before)

    - across several outcome variables
        nighttime light as a proxy for output,
        MNREGA information to measure rural employment,
        agriculture market activities.

Estimate impact of Gujarat rural road project on economic activities: Methodology

The beta coefficient ($\boldsymbol{\beta}$) estimates the difference in the average performance between the treatment and control groups in the years after 2016 relative to the years before.

$MMGSY$ takes the value 1 if village i is treated.

$Post_{2016}$ takes the value of 1 for 2017 onwards.

y_{it} denotes the outcome variable for village i at time t.

$$y_{it} = \sum_{t=2014}^{t=T} \boldsymbol{\beta} * MMGSY_i * Post_{2016_t} + \alpha_i + \delta_t + \epsilon_{it} \quad (1)$$

$$y_{it} = \sum_{t=2014,\, t\neq 2016}^{t=T} \boldsymbol{\beta_t} * MMGSY_i * D_t + \alpha_i + \delta_t + \epsilon_{it} \quad (2)$$

α_i and δ_t denote the cross section and time fixed effects.

D_t takes the value of 1 for the respective years.

The beta coefficients ($\boldsymbol{\beta_t}$) estimate the differences in the average performance between the treatment and control groups in other years relative to 2016.

Estimate impact of Gujarat rural road project: Results on output

Nighttime light intensity **increased** by **7.2 percent** in the treated villages relative to all control villages in the post-2016 period relative to the years before.

Nighttime light intensity **increased** by **1.9 percent** in the treated villages relative to the control villages with 500-1000 people in the post-2016 period relative to the years before.

This roughly translates to **0.5-2.2 percent increase in local output** in the treated villages, relative to the control villages.

Nighttime light Intensity
Treated vs all control villages
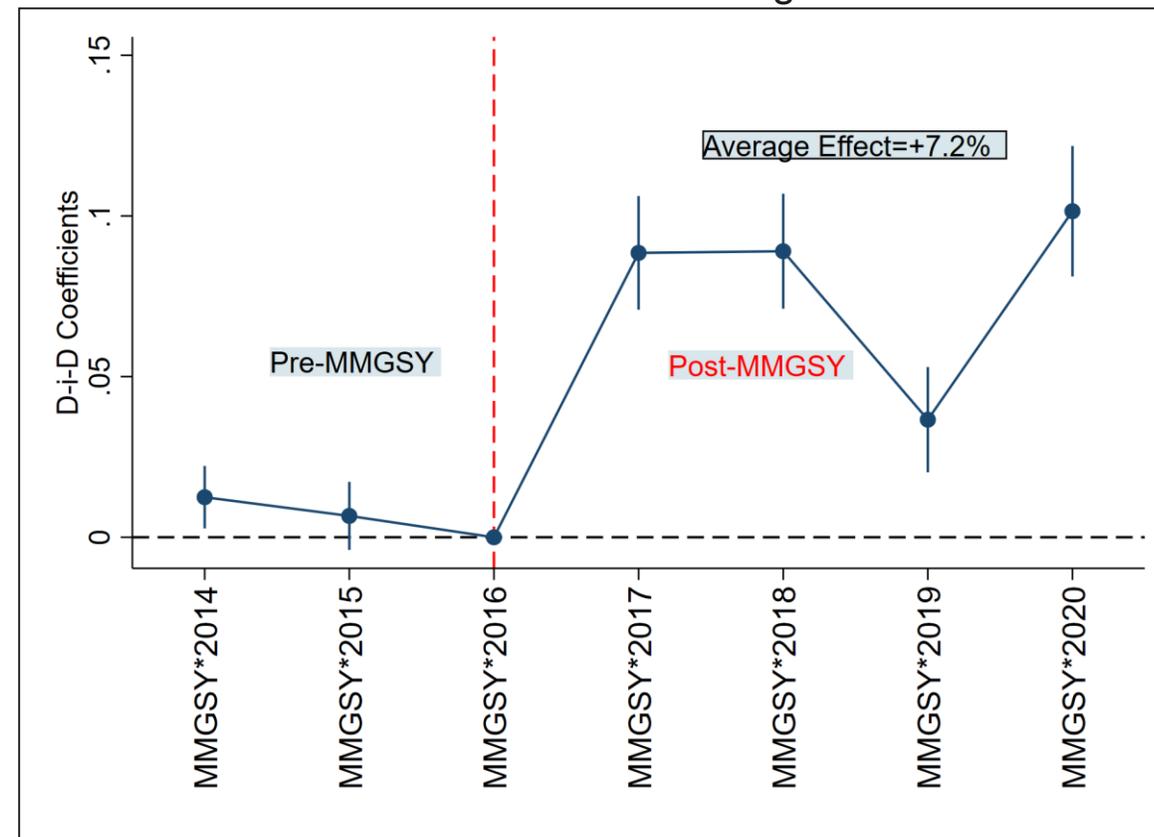
Notes: Based on both annual and long-term growth rate comparisons for a sample of 188 countries, Henderson, Storeygard, and Weil (2012) argue for an elasticity of GDP growth to nightlight growth of 0.3. Beyer et al. (2018) estimates this elasticity to be 0.248 for South Asian countries.

Estimate impact of Gujarat rural road project: Results on rural employment

Person-days worked increased by 11 percent in the treated blocks relative to the control blocks in the post 2016 period relative to the years before.

Persons demanded work increased by 5.9 percent in the treated blocks relative to the control blocks in the post 2016 period relative to the years before.

Person-days worked of public work program
Treated vs all control census blocks
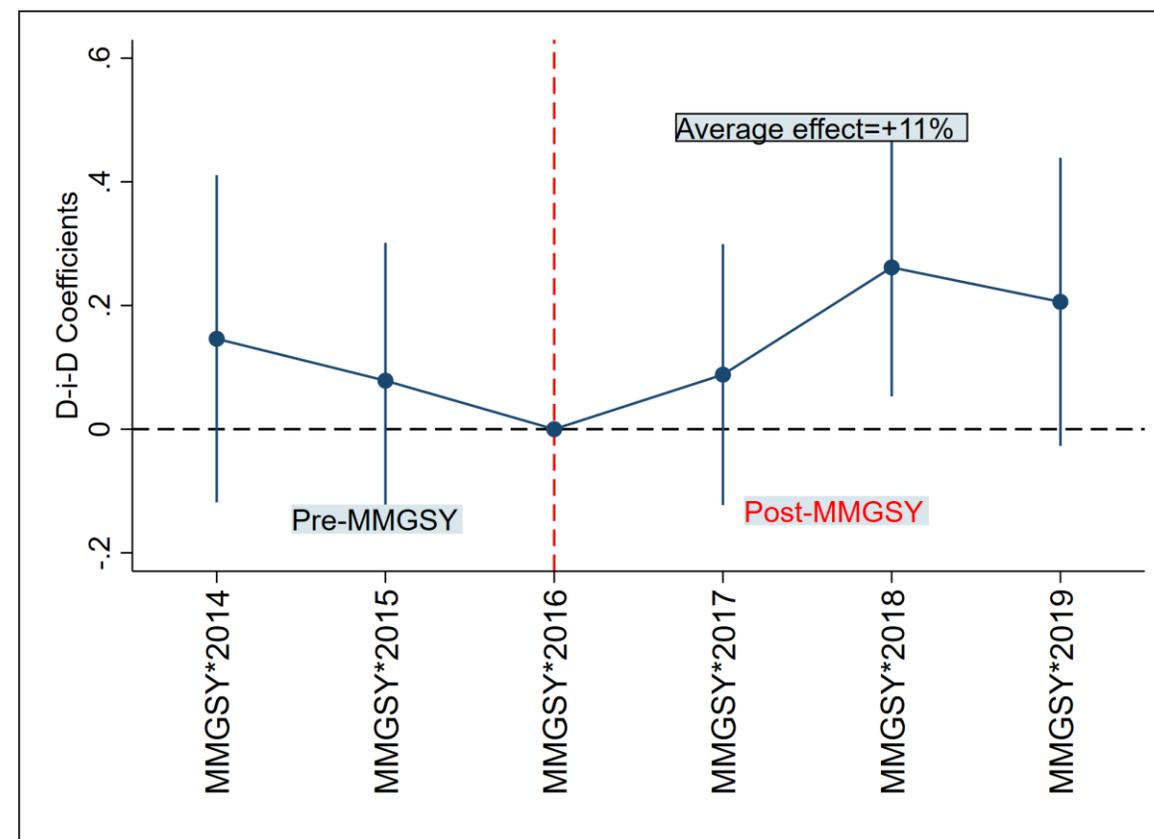
Impact of Gujarat rural road project: Discussion

Extensions of the simulation:
- Robustness check on new construction vs. upgrading.
- Exact road location information.
- Access to hospitals and schools.

Extensions of the estimation:
- Refine controls using distance between treated and control villages.
- Exact road location and completion information:
  - Staggered Difference-in-Differences analysis
- Agriculture activities:
  - Weak impact on the quantity of cotton (a major crop) arrived at the agriculture markets.
  - More analysis on agriculture activities using alternative data sources
- Utilization of financial services.

Broader issues :
- Heterogeneity: quantity vs. quality?
- Network effects: connect to what?
- Systems of systems: complementarity or substitutability between transport and IT?

Motivation

Spatial Data

Road Transport Performance Across India

Impact of Gujarat Rural Road Project (MMGSY)

Team and Partnership

Team members

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Prof. Riccardo Crescenzi, LSE

Investment Operation teams of AIIB

Complaints-resolution, Evaluation and Integrity Unit of AIIB

Thank you.