MEASURE CONNECTIVITY AND ASSESS PROJECT IMPACT

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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
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

\[
\text{Accessiblity} \times 100\% \div \text{Proximity}
\]
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.
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.
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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
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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 $\times$ 1.5 hr = 120 km)

- **Accessibility**: within a 90 minutes drive, how many people can one reach using existing road network *in reality*?
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 proximity:
- 120 km radius without network use.

Service area for accessibility:
- 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.
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

km

0 290 580 1,160
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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
India’s performance falls far behind most European countries, but performance varies significantly across major states

<table>
<thead>
<tr>
<th>STATE</th>
<th>POPULATION (mil. People)</th>
<th>POPULATION DENSITY (peop/km²)</th>
<th>PROXIMITY (mil. people)</th>
<th>ACCESSIBILITY (mil. people)</th>
<th>TRANSPORT PERFORMANCE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCT of Delhi</td>
<td>18</td>
<td>12059</td>
<td>61</td>
<td>48</td>
<td>66</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>121</td>
<td>392</td>
<td>20</td>
<td>8</td>
<td>41</td>
</tr>
<tr>
<td>Gujarat</td>
<td>66</td>
<td>350</td>
<td>16</td>
<td>7</td>
<td>40</td>
</tr>
<tr>
<td>Haryana</td>
<td>28</td>
<td>625</td>
<td>43</td>
<td>17</td>
<td>39</td>
</tr>
<tr>
<td>Karnataka</td>
<td>65</td>
<td>339</td>
<td>17</td>
<td>6</td>
<td>37</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>76</td>
<td>586</td>
<td>21</td>
<td>6</td>
<td>36</td>
</tr>
<tr>
<td>Kerala</td>
<td>37</td>
<td>874</td>
<td>19</td>
<td>6</td>
<td>36</td>
</tr>
<tr>
<td>Punjab</td>
<td>30</td>
<td>595</td>
<td>22</td>
<td>6</td>
<td>31</td>
</tr>
<tr>
<td>Telangana</td>
<td>38</td>
<td>328</td>
<td>17</td>
<td>6</td>
<td>29</td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>217</td>
<td>902</td>
<td>42</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>West Bengal</td>
<td>98</td>
<td>1132</td>
<td>41</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>52</td>
<td>324</td>
<td>13</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td>Bihar</td>
<td>117</td>
<td>1231</td>
<td>50</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>76</td>
<td>220</td>
<td>15</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>Chhattisgarh</td>
<td>28</td>
<td>204</td>
<td>12</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>78</td>
<td>253</td>
<td>14</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>Jharkhand</td>
<td>37</td>
<td>454</td>
<td>26</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>Assam</td>
<td>35</td>
<td>426</td>
<td>12</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Odisha</td>
<td>45</td>
<td>290</td>
<td>13</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>India (all)</td>
<td>1311</td>
<td>412</td>
<td>26.9</td>
<td>7.4</td>
<td>28</td>
</tr>
</tbody>
</table>

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.

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.
Public expenditure increases road length but not always performance

- **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.

<table>
<thead>
<tr>
<th></th>
<th>Count</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treated villages</strong> (&lt;500 people)</td>
<td>2867</td>
<td>13%</td>
</tr>
<tr>
<td>Control villages</td>
<td>3889</td>
<td>17%</td>
</tr>
<tr>
<td>(500-1000 people)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control villages</td>
<td>15358</td>
<td>68%</td>
</tr>
<tr>
<td>(&gt;1000 people)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban areas</td>
<td>503</td>
<td>2%</td>
</tr>
<tr>
<td>Total adm. units</td>
<td>22617</td>
<td>100%</td>
</tr>
</tbody>
</table>

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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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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?

<table>
<thead>
<tr>
<th>Speed downgrade</th>
<th>Length (km)</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>From 91 unchanged</td>
<td>25</td>
<td>0.1%</td>
</tr>
<tr>
<td>From 71 unchanged</td>
<td>260</td>
<td>1.3%</td>
</tr>
<tr>
<td>From 51 to 31 kmph</td>
<td>344</td>
<td>1.7%</td>
</tr>
<tr>
<td>From 31 to 11 kmph</td>
<td>2033</td>
<td>10.0%</td>
</tr>
<tr>
<td>From 11 to 5 kmph</td>
<td>17683</td>
<td>86.9%</td>
</tr>
<tr>
<td>Total</td>
<td>20345</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

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

Accessibility (Millions of People)

<table>
<thead>
<tr>
<th></th>
<th>State</th>
<th>Treated villages</th>
<th>Other locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Results</td>
<td>7.2</td>
<td>3.5</td>
<td>7.3</td>
</tr>
<tr>
<td>Simulated Results</td>
<td>7.1</td>
<td>2.7</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Accessibility (% increase):
- State: +2.5%
- Treated villages: +29.4%
- Other locations: +2.4%

Transport Performance (%)

<table>
<thead>
<tr>
<th></th>
<th>State</th>
<th>Treated villages</th>
<th>Other locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Results</td>
<td>39.6</td>
<td>19.9</td>
<td>40.0</td>
</tr>
<tr>
<td>Simulated Results</td>
<td>38.6</td>
<td>15.6</td>
<td>39.1</td>
</tr>
</tbody>
</table>

Transport Performance (% increase):
- State: +0.6%
- Treated villages: +3.8%
- Other locations: +0.9%
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 ($\beta$) estimates the difference in the average performance between the treatment and control groups in the years after 2016 relative to the years before.

$$y_{it} = \sum_{t=2014}^{T} \beta \cdot MMGSY_i \cdot Post_{2016t} + \alpha_i + \delta_t + \epsilon_{it}$$

$y_{it}$ denotes the outcome variable for village $i$ at time $t$. $MMGSY$ takes the value 1 if village $i$ is treated. $Post_{2016}$ takes the value of 1 for 2017 onwards.

$\alpha_i$ and $\delta_t$ denote the cross section and time fixed effects.

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

$$y_{it} = \sum_{t=2014, t\neq 2016}^{T} \beta_t \cdot MMGSY_i \cdot D_t + \alpha_i + \delta_t + \epsilon_{it}$$

$D_t$ takes the value of 1 for the respective years.
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.

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.
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?
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Impact of Gujarat Rural Road Project (MMGSY)

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Team members

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Thank you.