Measuring Urban Form/Street Space and the Effect on Emissions in China

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China Sustainable Transportation Center
Outline

1. Measuring TOD
2. Measuring Street Space
3. Modelling CO2 Emissions in Jinan, China
4. Conclusion and Discussion
Measuring TOD in China
Transit Oriented Development

A concept first raised by Peter Calthorpe in the 1990s, in general refers to an urban environment with high densities, mixed land uses, and quality public space within easy walking distance of a transit stop.
TOD Measuring Framework

**TOD Index**

- **Quantity**
  - Line Network Density (+)
  - Station Density (+)
  - Urban Pop Coverage Ratio (+)
  - Urban Emp Coverage Ratio (+)

- **Density**
  - Pop Density (+)
  - Emp Density (+)
  - Density Gradient (+)

- **Diversity**
  - Land Use Mix (+)
  - Number of Feed Bus Lines (+)
  - Ground-floor Retail Density (+)

- **Design**
  - Street Network Density (+)
  - Number of Station Entrances (+)
  - Number of Car Parking (-)
  - Highway Density (-)

*(Station 800m-Buffer)*
TOD Quality indicators - Density

① Population Density
Population density within 800m buffers

② Employment Density
Employment positions within 800m buffers

③ Density Gradient
FAR within 400m to stations /FAR within 400m-800m to stations
Land use mix
= - Σ Pi * ln(Pi) / ln(6)
(residential, commercial, education, hospital, transportation, industry)
TOD Quality indicators - Diversity

⑤ Number of Feeder Bus = Number of Bus Lines in 100m buffer

⑥ Ground-floor Retail Density = Number of ground-floor retails / length of roads in 800m buffer area
TOD Quality indicators - Design

7. Street Network Density
All roads (except highways and expressways) length (km)/800m buffer area (km²)

8. Highway Density
Length of expressways (km)/800m buffer area (km²)
TOD Quality indicators - Design

⑨ Number of Station Entrance

⑩ Number of Car Parking
   = Number of Public Parking POIs within 200m buffer
### TOD Index Calculation - Indicator Weighting

**Information Entropy Weighting**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Pop Coverage Ratio (+)</td>
<td>0.21</td>
</tr>
<tr>
<td>Urban Emp Coverage Ratio (+)</td>
<td>0.19</td>
</tr>
<tr>
<td>Station Density (+)</td>
<td>0.31</td>
</tr>
<tr>
<td>Line Network Density (+)</td>
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<td>Pop Density (+)</td>
<td>0.12</td>
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<td>Emp Density (+)</td>
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<td>0.12</td>
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<td>Land Use Mix (+)</td>
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<table>
<thead>
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<td>Number of Food Bus Lines (+)</td>
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</tr>
<tr>
<td>Ground Floor Retail Density (+)</td>
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</tr>
<tr>
<td>Street Network Density (+)</td>
<td>0.11</td>
</tr>
<tr>
<td>Number of Station Entrances (+)</td>
<td>0.06</td>
</tr>
<tr>
<td>Number of Car Parking (−)</td>
<td>0.04</td>
</tr>
<tr>
<td>Highway Density (−)</td>
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**TOD Expert Weighting**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Urban Pop Coverage Ratio (+)</td>
<td>0.28</td>
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<tr>
<td>Urban Emp Coverage Ratio (+)</td>
<td>0.22</td>
</tr>
<tr>
<td>Station Density (+)</td>
<td>0.40</td>
</tr>
<tr>
<td>Line Network Density (+)</td>
<td>0.10</td>
</tr>
<tr>
<td>Pop Density (+)</td>
<td>0.13</td>
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<td>Emp Density (+)</td>
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</tr>
<tr>
<td>Density Gradient (+)</td>
<td>0.14</td>
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<td>Land Use Mix (+)</td>
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<table>
<thead>
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</thead>
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<tr>
<td>Ground Floor Retail Density (+)</td>
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<tr>
<td>Street Network Density (+)</td>
<td>0.00</td>
</tr>
<tr>
<td>Number of Station Entrances (+)</td>
<td>0.00</td>
</tr>
<tr>
<td>Number of Car Parking (−)</td>
<td>0.00</td>
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<tr>
<td>Highway Density (−)</td>
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**Adjusted Weighting**

<table>
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<th>Weighting</th>
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<tbody>
<tr>
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<td>Urban Emp Coverage Ratio (+)</td>
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<tr>
<td>Station Density (+)</td>
<td>0.40</td>
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<tr>
<td>Line Network Density (+)</td>
<td>0.10</td>
</tr>
<tr>
<td>Pop Density (+)</td>
<td>0.15</td>
</tr>
<tr>
<td>Emp Density (+)</td>
<td>0.10</td>
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<tr>
<td>Density Gradient (+)</td>
<td>0.15</td>
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<tr>
<td>Land Use Mix (+)</td>
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</table>

<table>
<thead>
<tr>
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<tr>
<td>Number of Food Bus Lines (+)</td>
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</tr>
<tr>
<td>Street Network Density (+)</td>
<td>0.00</td>
</tr>
<tr>
<td>Number of Station Entrances (+)</td>
<td>0.00</td>
</tr>
<tr>
<td>Number of Car Parking (−)</td>
<td>0.00</td>
</tr>
<tr>
<td>Highway Density (−)</td>
<td>0.00</td>
</tr>
</tbody>
</table>
China is facing severe air quality threats due to various factors, among which transportation, traffic congestion and increasing dependence on private vehicles are becoming ever more critical.

Transit-oriented development (i.e., TOD) has often been claimed as an effective solution to promote more sustainable travel among urban residents and to shape clean cities. However, no research explicitly links air quality and TOD patterns with empirical evidence in rapidly urbanizing China.

Research Question
Is a city with a higher degree of TOD in China associated with better air quality after controlling for other confounding factors?
Air Quality Data

Daily Air Quality Index were collected for 152 China major cities over year 2014 from China MEP website:

- 37 cities with either urban rail or bus-rapid-transit (BRT) system, among which
- 7 cities with both systems
- 17 cities with only urban rail system
- 15 cities with only BRT system
- 115 cities with no urban rail or BRT system

152 China cities with AQI record
Spatial Error Model Result

1) Urban Rail TOD index is significantly and negatively correlated with Year, Spring and Fall AQI;

2) BRT TOD index appears to have no significant relationship with air quality;

3) Impacts of energy use, urban green and road network are consistent with the literature;

4) Daily precipitation plays an important role in AQIs (except Fall AQI)

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Annual</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average daily precip.</td>
<td>-0.150*</td>
<td>-0.051</td>
<td>-0.032*</td>
<td>-0.052</td>
<td>-0.676*</td>
</tr>
<tr>
<td>Average daily temp.</td>
<td>0.147*</td>
<td>0.124*</td>
<td>0.117*</td>
<td>0.004</td>
<td>0.089</td>
</tr>
<tr>
<td>Average daily wind</td>
<td>-0.743*</td>
<td>-0.553**</td>
<td>-0.722**</td>
<td>-1.394***</td>
<td></td>
</tr>
<tr>
<td>Energy and industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Heating Provi.</td>
<td>10.484***</td>
<td>0.234***</td>
<td>-</td>
<td>-</td>
<td>14.559***</td>
</tr>
<tr>
<td>Log of Gasoline Coverage</td>
<td>1.073</td>
<td>0.455</td>
<td>0.799</td>
<td>1.615**</td>
<td>0.814</td>
</tr>
<tr>
<td>Second Industry as % GDP</td>
<td>0.070</td>
<td>-0.006</td>
<td>0.196*</td>
<td>-0.059</td>
<td>0.111</td>
</tr>
<tr>
<td>Urban form</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log of Urban Area</td>
<td>4.112</td>
<td>4.060</td>
<td>3.831</td>
<td>4.035</td>
<td>7.192</td>
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<tr>
<td>Green Space Coverage</td>
<td>-2.794*</td>
<td>-3.644*</td>
<td>-0.340</td>
<td>-3.612**</td>
<td>-5.209**</td>
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<tr>
<td>Road Area Coverage</td>
<td>0.410*</td>
<td>0.145</td>
<td>0.299</td>
<td>0.552</td>
<td>0.888**</td>
</tr>
<tr>
<td>Street Network Density</td>
<td>-0.597</td>
<td>-0.162</td>
<td>-0.633</td>
<td>-1.069*</td>
<td>-0.831</td>
</tr>
<tr>
<td>Rail TOD Index</td>
<td>-0.342*</td>
<td>-0.335**</td>
<td>-0.159</td>
<td>-0.485**</td>
<td>-0.477**</td>
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<tr>
<td>BRT TOD Index</td>
<td>0.143</td>
<td>0.800</td>
<td>0.266</td>
<td>0.645</td>
<td>0.593</td>
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<tr>
<td>Constant</td>
<td>73.354***</td>
<td>76.354***</td>
<td>36.147</td>
<td>65.562***</td>
<td>124.876***</td>
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<tr>
<td>Lambda</td>
<td>0.779**</td>
<td>0.813*</td>
<td>0.720*</td>
<td>0.767*</td>
<td>0.781**</td>
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<tr>
<td>Observations</td>
<td>152</td>
<td>152</td>
<td>152</td>
<td>152</td>
<td>152</td>
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<tr>
<td>Pseudo R2</td>
<td>0.685</td>
<td>0.707</td>
<td>0.549</td>
<td>0.583</td>
<td>0.666</td>
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<tr>
<td>Log Likelihood</td>
<td>-586.667</td>
<td>-571.045</td>
<td>-571.834</td>
<td>-510.369</td>
<td>-671.245</td>
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<td>sigma2</td>
<td>110.04</td>
<td>107.794</td>
<td>93.979</td>
<td>151.643</td>
<td>334.445</td>
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<td>Akaike Inf. Crit.</td>
<td>4207.33</td>
<td>1208.69</td>
<td>1175.67</td>
<td>1252.74</td>
<td>1376.49</td>
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<tr>
<td>Wald Test (df = 1)</td>
<td>310.196</td>
<td>442.647</td>
<td>180.358***</td>
<td>273.925***</td>
<td>315.696***</td>
</tr>
<tr>
<td>IR Test (df = 1)</td>
<td>78.961***</td>
<td>87.897***</td>
<td>55.538***</td>
<td>92.661***</td>
<td>93.170***</td>
</tr>
</tbody>
</table>

* p < 0.1
** p < 0.05
*** p < 0.01
Measuring Street Space in China
Why Measuring Street Space…

Complete Street
完整街道

Car-Oriented Roads
只考虑机动车的道路
Street Space Indicators

>> Identify sidewalks and bike lanes from street view images

Sidewalk existence $X_1$

Bike lane existence $X_2$

- Crossing facility existence $X_3$
- % Sidewalk with illegal parking $X_4$
- % Bike lane with illegal parking $X_5$
- % Street with tree shade $X_6$
- Street width $X_7$
- Bike lane isolation $X_8$
- Street wall continuity ratio $X_9$
- Street network density $X_{10}$
- Crossing density $X_{11}$
- Facility accessibility $X_{12}$
Street Space Indicators

> Identify crossing facilities from street view images
> - Crossing facilities include zebra strips, signal lamps, overpass and underpass
> - Multiple types of crossing facilities at the same spot count as one facility

Sidewalk existence $X_1$
Bike lane existence $X_2$

Crossing facility existence $X_3$

% Sidewalk with illegal parking $X_4$
% Bike lane with illegal parking $X_5$
% Street with tree shade $X_6$
Street width $X_7$
Bike lane isolation $X_8$
Street wall continuity ratio $X_9$
Street network density $X_{10}$
Crossing facility density $X_{11}$
Facility accessibility $X_{12}$
Street Space Indicators

Estimate the proportion of sidewalks/bike lanes occupied by illegal car parking from street view images.

- Sidewalk existence $X_1$
- Bike lane existence $X_2$
- Crossing facility existence $X_3$
- % Sidewalk with illegal parking $X_4$
- % Bike lane with illegal parking $X_5$
- % Street with tree shade $X_6$
- Street width $X_7$
- Bike lane isolation $X_8$
- Street wall continuity ratio $X_9$
- Street network density $X_{10}$
- Crossing facility density $X_{11}$
- Facility accessibility $X_{12}$
Street Space Indicators

Striping
Score: 1

Fence
Score: 2

Median
Score: 3

>> Identify the forms of bike lane isolation from street view images

Bike lane isolation $X_8$

- Street wall continuity ratio $X_9$
- Street network density $X_{10}$
- Crossing facility density $X_{11}$
- Facility accessibility $X_{12}$

Additional forms:
- Sidewalk existence $X_1$
- Bike lane existence $X_2$
- Crossing facility existence $X_3$
- % Sidewalk with illegal parking $X_4$
- % Bike lane with illegal parking $X_5$
- % Street with tree shade $X_6$
- Street width $X_7$
Street Space Indicators

- Sidewalk existence $X_1$
- Bike lane existence $X_2$
- Crossing facility existence $X_3$
- % Sidewalk with illegal parking $X_4$
- % Bike lane with illegal parking $X_5$
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- Street width $X_7$
- Bike lane isolation $X_8$
- Street wall continuity ratio $X_9$
- Street network density $X_{10}$
- Crossing facility density $X_{11}$
- Facility accessibility $X_{12}$

>> Identify street façade using building lots
Street Space Indicators

Using maximum intersection method based on arcpy library of ArcGIS to calculate the street-wall continuity ratio

Calculate street width as the distance from the street’s center line to the building facades on both sides (adapted from Harvey, 2014)
Street Space Indicators

- Sidewalk existence $X_1$
- Bike lane existence $X_2$
- Crossing facility existence $X_3$
- % Sidewalk with illegal parking $X_4$
- % Bike lane with illegal parking $X_5$
- % Street with tree shade $X_6$
- Street width $X_7$
- Bike lane isolation $X_8$
- Street wall continuity ratio $X_9$
- Street network density $X_{10}$
- Crossing facility density $X_{11}$
- Facility accessibility $X_{12}$

>> Extract the green pixels from street view images (SVI) based on a manually set greenness color range

>> Calculate the average green view index (GVI) of each interval point using the greenness proportion from four-direction SVI

>> Estimate %street with tree shade with the mean GVI of all interval points on a street segment
Identify and extract 7 daily facilities (farmers’ market, convenience store, restaurant, supermarket, leisure, bank and hospital) and 2 public transportation facilities (regular bus stop and metro station) from the POI database.

Calculate the nearest street network distance from a certain interval point to each of these facilities as $\text{Dis}_p$, where $p$ includes 9 POI categories.

Using the distance decay function to calculate the accessibility index to each of these facilities:

$$\text{Acc}_p = \begin{cases} 
0, & \text{if } \text{Dis}_p > 2400 \\
1, & \text{if } \text{Dis}_p \leq 400 \\
\frac{188177}{(\text{Pow}(\text{Dis}_p, 2.9475) + 34259163)}, & \text{if } 400 < \text{Dis}_p < 2400 
\end{cases}$$

Then, the average facility accessibility for each interval point was calculated:

$$\text{Acc} = \sum_0^9 \text{Acc}_p \times 1/9$$

Adapted from Lu (2013)
## Street Space Indicators

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Indicator</th>
<th>Walkability</th>
<th>Bikeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Sidewalk existence (+)</td>
<td></td>
<td>Bike lane existence (+)</td>
</tr>
<tr>
<td></td>
<td>Crossing facility existence (+)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>% Sidewalk with illegal parking (-)</td>
<td></td>
<td>% Bike lane with illegal parking (-)</td>
</tr>
<tr>
<td>Comfort</td>
<td>Street width (-)</td>
<td></td>
<td>Bike lane isolation (+)</td>
</tr>
<tr>
<td></td>
<td>Street wall continuity ratio (+)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Convenience</td>
<td>Street network density (+)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crossing facility density (+)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Facility accessibility (+)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Indicators marked as “+” imply a positive relationship with street score, while indicators marked as “-” imply a negative relationship with street score.
Clusters of high-walkability streets form in city centers, while in periphery areas, street walkability fades out.
Street BIKE Score

>> The overall bike scores are lower than walk scores;

>> A preliminary bikeable street network is evident in Tianjin, Kunming and Shijiazhuang.
Modelling CO2 Emissions in Jinan, China
Case Study: Jinan

City population: 3.4 million
Study area: 533 sq. km

An integrated GIS Database for Jinan
Jinan Household Survey

2,540 households from 104 neighborhoods
Socio-demographics, weekly travel diary, attitudes

Table 1
Comparisons of household characteristics between the survey sample and city population in Jinan.

<table>
<thead>
<tr>
<th></th>
<th>Survey sample</th>
<th>City average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household size (persons)</td>
<td>3.01</td>
<td>2.98</td>
</tr>
<tr>
<td>Household income (RMB/year)</td>
<td>33,873</td>
<td>38,763</td>
</tr>
<tr>
<td>Car ownership (cars/100 people)</td>
<td>20.5</td>
<td>19.6</td>
</tr>
<tr>
<td>Mode share - car</td>
<td>19%</td>
<td>15%</td>
</tr>
<tr>
<td>More share - bus</td>
<td>17%</td>
<td>18%</td>
</tr>
</tbody>
</table>

Traditional
GRID
Enclave
Superblock
Travel Distance by Neighborhood Types

Kilometers per HH per week

- Walk
- Bike
- Ebike
- Motorcycle
- Bus
- Taxi
- Car

Traditional
- 11 walk
- 35 bike
- 55 ebike
- 10 motorcycle
- 10 bus
- 10 taxi
- 27 car

Grid
- 21 walk
- 20 bike
- 20 ebike
- 20 motorcycle
- 20 bus
- 20 taxi
- 18 car

Enclave
- 20 walk
- 21 bike
- 21 ebike
- 21 motorcycle
- 24 bus
- 24 taxi
- 17 car

Superblock
- 88 walk
- 88 bike
- 88 ebike
- 88 motorcycle
- 24 bus
- 24 taxi
- 14 car

Photos of traditional, grid, enclave, and superblock neighborhoods.
## Urban Form/Street Space Indicator Framework

<table>
<thead>
<tr>
<th><strong>Urban Form</strong></th>
<th><strong>Street Space</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Density</strong></td>
<td></td>
</tr>
<tr>
<td>Floor area ratio</td>
<td>Street network density</td>
</tr>
<tr>
<td>Building coverage</td>
<td>Density of crossing facilities</td>
</tr>
<tr>
<td>Population density</td>
<td>Density of ground floor retails</td>
</tr>
<tr>
<td><strong>Diversity</strong></td>
<td></td>
</tr>
<tr>
<td>Land use mix index</td>
<td>% of streets with dedicated bus lanes</td>
</tr>
<tr>
<td>Number of POIs</td>
<td>% of streets with bike lanes</td>
</tr>
<tr>
<td>Job-housing balance</td>
<td>% of streets with sidewalk</td>
</tr>
<tr>
<td></td>
<td>Street right of way mix index</td>
</tr>
<tr>
<td></td>
<td>Density of bus stops</td>
</tr>
<tr>
<td><strong>Design</strong></td>
<td></td>
</tr>
<tr>
<td>Land area</td>
<td>Building setback distance</td>
</tr>
<tr>
<td>Parking lots per household</td>
<td>% of streets with tree shade</td>
</tr>
<tr>
<td>Distance b/w entrances</td>
<td>Street wall continuity</td>
</tr>
<tr>
<td></td>
<td>% of streets with curbside parking</td>
</tr>
<tr>
<td></td>
<td>% of streets with illegal parking</td>
</tr>
</tbody>
</table>

![Traditional](image1.png) ![Grid](image2.png) ![Enclave](image3.png) ![Superblock](image4.png)
Direct Modelling Approach

- Principle component analysis
- Household vehicle portfolio choice model
- Household travel distance models

Table 3
Fuel energy intensity and CO₂ emission factor values in Jinan, China.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Energy consumption factor$^a$ (mj/veh·km)</th>
<th>CO₂ emission factor$^b$ (kg/veh·km)</th>
<th>Trip occupancy rate$^b$ (person/veh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>2.962</td>
<td>0.199</td>
<td>1.3</td>
</tr>
<tr>
<td>Bus</td>
<td>10.680</td>
<td>0.741</td>
<td>18.0</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>0.612</td>
<td>0.041</td>
<td>1.1</td>
</tr>
<tr>
<td>Ebike</td>
<td>0.076</td>
<td>0.026</td>
<td>1.1</td>
</tr>
</tbody>
</table>

$^a$ Based on Cherry, Weinert, and Xinmiao (2009) and Jiang et al. (2015).

$^b$ Trip occupancy rates for car, motorcycle and ebike were derived from the household sample. The trip occupancy rate for bus was obtained from Jiang et al. (2015).
Household travel distance model: Double-Hurdle Model
- account for the excess number of zero values in the distributions of dependent travel distance variables

- **Stage 1 choice model** categorizes households as either generating any distance or not.
- It contains a participation equation where the latent variable $d^*$ represents, in this case, the decision to travel as a linear function of first-hurdle regressor (z),

\[ d^* = \alpha' z + u \quad u \sim \mathcal{N}(0, 1) \quad (1) \]

- **Stage 2 distance model** estimates the log-transformed VKT generated for households with any(positive) VMT. It features a consumption equation, characterized by the latent variable $y^*$, the distance travelled, as a linear function of second-hurdle regressors (x).

\[ y^* = \beta' x + v \quad v \sim \mathcal{N}(0, 1) \quad (2) \]

- Thus the observed distance traveled $y$:

\[ y = \begin{cases} y^*, & \text{if } d^* > 0 \text{ and } y^* > 0 \\ 0, & \text{otherwise} \end{cases} \quad (3) \]

- The “vehicle owned” variable will be replaced by the predicted values from the Ownership MNL model.
Hold-out Validation
Conclusion and Discussion
Conclusion

• **Part I:** A TOD performance indicator system reflecting the quantity and quality dimensions was developed and composite TOD indexes were estimated for 37 Chinese cities with either urban rail or BRT systems. The rail TOD index correlates negatively with air pollution concentrations measured by annual and seasonal average AQIs (except for the summer average AQI).

• **Part II:** Utilizing open source data, we put forward a methodology to comprehensively and objectively measure street walkability and bikeability in China.

• **Part III:** Through the Jinan case, we demonstrated advantages of a direct modelling approach for CO2 assessment:
  ✔ Provides flexibility on data requirements
  ✔ Captures the effects of both the land form and street form variables on travel outcomes
  ✔ Integrates the vehicle ownership portfolio choice model and the travel distance models, so that it produces travel behavior outcomes to assist story-telling and to have potential for extension to additional impact analysis (e.g., NOx emissions)
  ✔ Uses a holdout validation to address the over-fitting problem of models and to enhance its reliability and robustness for assessing future scenarios under the local context
Using Open Source Data to Measure Street Walkability and Bikeability in China: A Case of Four Cities

Peiqin Gu1, Zhiyan Han2, Zheqing Cao3, Yulin Chen4, and Yang Jiang1

Whether people would choose to walk or ride a bike for their daily travel is affected by how desirable the environment is for walking and biking. To better inform urban planning and design practices, motorized traffic, and tools for measuring walkability and bikeability have emerged in western countries over the last decade. However, such tools are still rare in developing countries, partially due to the scarcity of urban data. Utilizing open source data, this paper first puts forward a method to comprehensively and objectively measure street walkability and bikeability in China. The methodology was applied to four Chinese cities: Tianjin, Chongqing, Kunming, and Shijiazhuang. Analyses showed the following results: (1) city center tend to have higher walkability than suburban areas; (2) a preliminary bike street network exists in most cities (e.g., mountainous cities), but the presence of bike lanes on streets is much lower than that of sidewalks; (3) the problem of parking on both sidewalks and bike lanes is severe, especially in city center; (4) biking safety and comfort is compromised due to a lack of physically separated bike lanes; and (5) the street walkability continuity varies from place to place whereas the street network in traditional city centers is much denser than newly developed out-in-open areas. The end of the paper provides corresponding policy implications.

1. Introduction

China’s urban planning and design practices are lagging behind the need for high-quality urban spaces. This is particularly true in the urban built environment (UDE) where walkability and bikeability are lacking. With an increasing population and global competition, China needs to change its urban planning and design practices to make its cities more pedestrian-friendly. To improve these practices, it is necessary to develop a comprehensive and reliable method to measure walkability and bikeability in China.

2. Methodology

The methodology includes the following steps: (1) collecting data from open-source sources; (2) processing data to derive a network of streets and sidewalks; (3) measuring walkability and bikeability; and (4) analyzing the results.

3. Results

The results showed that the four cities have different levels of walkability and bikeability. Tianjin has the highest walkability, while Kunming has the lowest. Chongqing and Shijiazhuang have similar levels of walkability and bikeability.

4. Discussion

The results highlight the importance of improving walkability and bikeability in China. The government should invest in improving the street network and bike lanes to make cities more pedestrian-friendly and bikeable.

5. Conclusion

This paper provides a comprehensive and reliable method to measure walkability and bikeability in China. The results show that the four cities have different levels of walkability and bikeability. The government should invest in improving the street network and bike lanes to make cities more pedestrian-friendly and bikeable.
Building Function Classification
Building Age Estimation