Lecture 14: Urban Infrastructure

Prof. Eduardo A. Haddad
Brazil's GDP loses R$156.2 billion, owing to traffic congestion in São Paulo

October 21, 2015

By José Tadeu Arantes

Agência FAPESP – How much does it cost you to be stuck in traffic in São Paulo? This question has now been answered with precision. “People who commute by car are spending 100 minutes per day on average in the city’s traffic between home and work,” says economist Eduardo Haddad, Full Professor of Economics at the University of São Paulo’s School of Economics, Administration & Accounting (FEA-USP). “Considering the structural characteristics of metropolitan São Paulo and the mobility patterns found in other Brazilian cities, this commute could be shortened by 30 minutes.”

“The resulting productivity gain would add 2.83% to Brazil’s gross domestic product (GDP), which reached R$5.5 trillion in 2014. In other words, it would add R$156.2 billion to our collective output, and this could translate into extra consumption, corresponding to R$97.6 billion by the Brazilian population.” Haddad coordinated a research project entitled “Mobility, accessibility and
Brazil’s GDP loses R$156.2 billion, owing to traffic congestion in São Paulo

Residents in São Paulo Metropolitan Region (RMSP) spend on average half an hour more in commuting time than expected.

If such excessive mobility friction were eliminated, national GDP could be 2.83% higher.

The City of São Paulo would absorb 50% of the potential benefit.
How much does it cost to be stuck in traffic in São Paulo?


“Mobility in Cities – Distributional Impact Analysis of Transportation Improvement in Metropolitan Region São Paulo”, *World Bank*

FAPESP, CNPq, World Bank
São Paulo Metropolitan Region is the financial and economic center of Brazil

Largest urban agglomeration in the country

- 10.3 % of national population (2010)
- 18.9 % of Brazilian GDP (2009)

The city of São Paulo is the core of the metropolitan area

- 5.9 % of national population (2010)
- 12.0 % of Brazilian GDP (2009)

<table>
<thead>
<tr>
<th></th>
<th>Area (000 km²)</th>
<th>Population (000 000)</th>
<th>GDP (USD billion)</th>
<th>Per capita GDP (USD)</th>
<th>HDI 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>São Paulo</td>
<td>1.5</td>
<td>11.3</td>
<td>194</td>
<td>17,221</td>
<td>0.841</td>
</tr>
<tr>
<td>SPMR</td>
<td>7.9</td>
<td>19.7</td>
<td>306</td>
<td>15,558</td>
<td>0.813</td>
</tr>
<tr>
<td>Brazil</td>
<td>8,514.9</td>
<td>190.8</td>
<td>1,619</td>
<td>8,486</td>
<td>0.665</td>
</tr>
</tbody>
</table>
The rapid process of urban expansion around São Paulo’s CBD...
... was not followed by the implementation of adequate public transport infrastructure

Average speed by motorized vehicles in the City of São Paulo during peak hours (in km/h) versus Population in SPMR
Traditional approach to estimate the direct impacts of urban transportation projects

Estimates of the individual value of travel time

- Empirical evidence from behavioral and non-behavioral models of modal choice suggest that the value of time saved in commuting represents a percentage of the individual hourly wage (10% to 50%)

Information on changes in travel time associated with the project

Parameters of the labor market of reference
What should we take into account in the calculation of the systemic economic effects?

Heterogeneity (individual and spatial)

Mobility *versus* Accessibility

Effects on labor productivity

Income flows and trade flow in the context of a metropolitan system

Supply and demand of transportation services

Sound economic theory
São Paulo Metropolitan Region (SPMR)

Employment density

Average household income

Population density

Share of commuting by public transportation
Higher wage (>20 SM)
The city of São Paulo receives daily an inflow of almost one million commuters (15.4% of workers in the city)
Mobility X Accessibility

“Mobility measures the ability to move from one place to another”

“Accessibility is defined as the potential of opportunities for interaction.” (Hansen, 1959)
High levels of mobility can, but do not necessarily, reflect high levels of accessibility...
Hansen’s formulation

\[ A_{im} = \sum_{j=1}^{n} O_j f(t) \]

- \( A = \text{Accessibility} \)
- \( j = 460 \text{ zones} \)
- \( O_j = \text{Jobs in } j \)
- \( t = \text{Commuting time} \)
- \( i = 460 \text{ zones} \)
- Mode = 1 Private vehicle, 2 Public transportation
- \( f(t) = e^{-\alpha t} \)
- \( \alpha \approx 0.01154 \)
- Defined such that \( f(60) = 0.5 \)
Accessibility to jobs in SPMR

Accessibility by private vehicle

Accessibility by public transportation
Accessibility to jobs and unemployment in SPMR

Accessibility by private vehicle

Accessibility by public transportation

Unemployment
Commuting time and productivity

Workers with longer daily commuting are less productive

- **Theoretical support** (Zenou e Smith, 1995; Zenou, 2002; Brueckner e Zenou, 2003; Ross and Zenou, 2008; Zenou, 2008)

- On-the-job effort is negatively related to commuting time

- **Empirical support** (Van Ommeren and Gutiérrez-i-Puigarnau, 2009; Porsse et al., 2012)

- Excessive commuting time may induce workers to arrive late or leave early; it also increases the frequency of absenteeism, reducing workers’ productivity
Accessibility to jobs and productivity

Workers with better access to available jobs are more productive

- Theoretical support ("matching")
- Effective size of the labor market
  - Efficiency of the transportation system
  - Relative location of jobs and residences
  - Helps explaining workers’ productivity
- How many jobs can a worker access in, say, 60 minutes?
- Empirical support
General features of the spatial computable general equilibrium (SCGE) model

Model based on simultaneous optimization of the behavior of individual consumers and firms, subject to resource constraints

Fully specified interregional input-output system (trade flows)

Focus on SPMR
- 39 municipalities + rest of the State of Sao Paulo + rest of Brazil

56 sectors, 110 commodities

Basic database at the municipality level (2008)

*Mapping labor payments from place of work to place or residence*

*Different patterns of household consumption by place of residence*

Reference: Haddad and Hewings (2005)
Input-output relations embedded in the SCGE model

**Place of production**

Activities

- Intermediate consumption
- Value added
- Gross output

Factors of production

- Intermediate consumption
- Value added
- Gross output

**Place of residence**

Households, firms and government

- Earned labor income
- Other earned income
- Taxes and transfers

**Place of consumption**

Activities, households, firms and govt.

- Intermediate consumption
- Household consumption
- Other final demand

Commodities

- Local demand
- Interregional and international imports

Commodities

- Local production
- Interregional exports
The integrated modeling framework
Production function of sector $j$ in municipality $r$

- Output
  - Intermediate inputs
    - Domestic
      - Region 1
      - Region n
    - Imported
      - Region n
  - Primary factors
    - Capital
      - Region 1
      - Region n
    - Labor
      - Region n

Place of production

Place of residence
Causal relations underlying the system of equations of the SCGE model

- Decrease in labor productivity
  - Increase the price of composite goods
  - Decrease (increase) real regional income: firms, investors, households
  - Firms: less (more) competitive
    Investors: potential lower (higher) returns
    Households: "poorer" ("richer")
  - Lower (higher) domestic demand
    Lower (higher) external demand
  - Lower (higher) output by firms
  - Lower (higher) demand for primary factors
  - Pressure on primary factor prices to decrease (increase)
  - Prices decline (increase)

- Increase in labor requirement per unit of output
  - Demand for labor increases
  - Pressure on labor prices to increase (output more labor-intensive)
  - Exceeds demand of labor

- Prices decline (increase)
  - Increase price of labor
  - Prices increase

- Decrease (increase) real regional income: firms, investors, households
  - Firms: less (more) competitive
    Investors: potential lower (higher) returns
    Households: "poorer" ("richer")
  - Lower (higher) domestic demand
    Lower (higher) external demand
  - Lower (higher) output by firms
  - Lower (higher) demand for primary factors
  - Pressure on primary factor prices to decrease (increase)
  - Prices decline (increase)

- Prices decline (increase)
  - Increase price of labor
  - Prices increase
What are the distributional impacts of urban mobility policies?

Enhance our understanding of the distributional impacts of mobility improvements in Sao Paulo (*trade-offs*)

1. **Infrastructure-related interventions:**
   - Expansion of the network of mass-transit public transportation

2. **Urban mobility policies:**
   - Monetary disincentives to the use of cars
## Simulations – 10 scenarios

<table>
<thead>
<tr>
<th>Investments Only</th>
<th>Scenario 1 – Metro and Train developments until year 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scenario 2 – Metro, Train and Bus corridor development until year 2020</td>
</tr>
<tr>
<td></td>
<td>Scenario 3 – Metro and Train developments until year 2025</td>
</tr>
<tr>
<td></td>
<td>Scenario 4 – Metro, Train and Bus corridor development until year 2025</td>
</tr>
<tr>
<td>Investments + Tax</td>
<td>Scenario 5 – Metro, Train and Bus corridor development until year 2025, and 30% increase in fuel price</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Changes in policies (fees, toll, tax)</th>
<th>Scenario 6 – 30% increase of in fuel prices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scenario 7 – Implementation of urban toll (R$5,00)</td>
</tr>
<tr>
<td></td>
<td>Scenario 8 – 50% increase in parking cost in the entire SPMR</td>
</tr>
<tr>
<td></td>
<td>Scenario 9 – 50% increase in parking cost in the extended CBD</td>
</tr>
<tr>
<td></td>
<td>Scenario 10 – 50% increase in parking cost in the core of the CBD</td>
</tr>
</tbody>
</table>
## Results – mode shifts

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Auto generalized costs (min)</th>
<th>Var. (%)</th>
<th>Transit generalized costs (min)</th>
<th>Var. (%)</th>
<th>Auto trips</th>
<th>Transit trips</th>
<th>Percentage of transit trips (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 0</td>
<td>49,393,784</td>
<td>-</td>
<td>51,055,637</td>
<td>-</td>
<td>1,211,347</td>
<td>1,605,276</td>
<td>57.0%</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>49,346,714</td>
<td>-0.1%</td>
<td>48,645,136</td>
<td>-4.7%</td>
<td>1,211,951</td>
<td>1,604,674</td>
<td>57.0%</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>49,293,780</td>
<td>-0.2%</td>
<td>48,510,714</td>
<td>-5.0%</td>
<td>1,210,189</td>
<td>1,606,436</td>
<td>57.0%</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>49,168,278</td>
<td>-0.5%</td>
<td>47,626,573</td>
<td>-6.7%</td>
<td>1,203,601</td>
<td>1,613,022</td>
<td>57.3%</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>49,028,855</td>
<td>-0.7%</td>
<td>47,442,580</td>
<td>-7.1%</td>
<td>1,200,579</td>
<td>1,616,044</td>
<td>57.4%</td>
</tr>
<tr>
<td>Scenario 5</td>
<td>57,705,139</td>
<td>16.8%</td>
<td>47,174,920</td>
<td>-7.6%</td>
<td>1,097,304</td>
<td>1,719,319</td>
<td>61.0%</td>
</tr>
<tr>
<td>Scenario 6</td>
<td>58,351,603</td>
<td>18.1%</td>
<td>50,600,088</td>
<td>-0.9%</td>
<td>1,118,669</td>
<td>1,697,954</td>
<td>60.3%</td>
</tr>
<tr>
<td>Scenario 7</td>
<td>58,195,915</td>
<td>17.8%</td>
<td>50,879,975</td>
<td>-0.3%</td>
<td>1,114,858</td>
<td>1,701,766</td>
<td>60.4%</td>
</tr>
<tr>
<td>Scenario 8</td>
<td>49,097,676</td>
<td>-0.6%</td>
<td>50,896,886</td>
<td>-0.3%</td>
<td>1,182,994</td>
<td>1,633,630</td>
<td>58.0%</td>
</tr>
<tr>
<td>Scenario 9</td>
<td>49,021,173</td>
<td>-0.8%</td>
<td>50,921,652</td>
<td>-0.3%</td>
<td>1,192,138</td>
<td>1,624,486</td>
<td>57.7%</td>
</tr>
<tr>
<td>Scenario 10</td>
<td>49,119,771</td>
<td>-0.6%</td>
<td>50,786,838</td>
<td>-0.5%</td>
<td>1,158,818</td>
<td>1,657,807</td>
<td>58.9%</td>
</tr>
</tbody>
</table>
### Summary of long run impacts

**Travel Demand**

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
<th>Scenario 5</th>
<th>Scenario 6</th>
<th>Scenario 7</th>
<th>Scenario 8</th>
<th>Scenario 9</th>
<th>Scenario 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit trips (% in total)</td>
<td>56.99</td>
<td>56.97</td>
<td>57.03</td>
<td>57.27</td>
<td>57.38</td>
<td>61.04</td>
<td>60.28</td>
<td>60.42</td>
<td>58.00</td>
<td>57.67</td>
<td>58.86</td>
</tr>
<tr>
<td>Generalized cost of private vehicle trips (in % change)</td>
<td>-</td>
<td>-0.095</td>
<td>-0.202</td>
<td>-0.457</td>
<td>-0.739</td>
<td>16.827</td>
<td>18.136</td>
<td>17.820</td>
<td>-0.599</td>
<td>-0.754</td>
<td>-0.555</td>
</tr>
<tr>
<td>Generalized cost of transit trips (in % change)</td>
<td>-</td>
<td>-4.721</td>
<td>-4.985</td>
<td>-6.716</td>
<td>-7.077</td>
<td>-7.601</td>
<td>-0.892</td>
<td>-0.344</td>
<td>-0.311</td>
<td>-0.262</td>
<td>-0.526</td>
</tr>
</tbody>
</table>

**Gini**

<p>| | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wage</td>
<td>0.6006</td>
<td>0.5976</td>
<td>0.5970</td>
<td>0.5957</td>
<td>0.5948</td>
<td>0.5847</td>
<td>0.5907</td>
<td>0.5893</td>
<td>0.5982</td>
<td>0.5990</td>
<td>0.5959</td>
</tr>
<tr>
<td>Commuting time</td>
<td>0.4120</td>
<td>0.4020</td>
<td>0.4010</td>
<td>0.3990</td>
<td>0.3973</td>
<td>0.3904</td>
<td>0.4044</td>
<td>0.3979</td>
<td>0.4094</td>
<td>0.4104</td>
<td>0.4061</td>
</tr>
</tbody>
</table>

**p 90 / p 10**

<p>| | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wage</td>
<td>4.65</td>
<td>4.66</td>
<td>4.65</td>
<td>4.74</td>
<td>4.54</td>
<td>4.25</td>
<td>4.63</td>
<td>4.67</td>
<td>4.65</td>
<td>4.65</td>
<td>4.66</td>
</tr>
<tr>
<td>Commuting time</td>
<td>11.00</td>
<td>8.07</td>
<td>8.07</td>
<td>10.93</td>
<td>8.56</td>
<td>9.12</td>
<td>11.00</td>
<td>13.05</td>
<td>10.47</td>
<td>10.81</td>
<td>11.04</td>
</tr>
</tbody>
</table>

**Average Indicators**

<p>| | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wage (BRL)</td>
<td>761.91</td>
<td>783.03</td>
<td>784.41</td>
<td>793.29</td>
<td>796.24</td>
<td>781.85</td>
<td>748.90</td>
<td>746.38</td>
<td>760.91</td>
<td>761.70</td>
<td>759.27</td>
</tr>
<tr>
<td>Commuting time (min)</td>
<td>52.14</td>
<td>50.25</td>
<td>50.07</td>
<td>49.55</td>
<td>49.23</td>
<td>50.57</td>
<td>53.41</td>
<td>54.50</td>
<td>52.33</td>
<td>52.20</td>
<td>52.70</td>
</tr>
</tbody>
</table>

**RMSP GRP (in % change)**

<p>| | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-</td>
<td>0.879</td>
<td>0.919</td>
<td>1.259</td>
<td>1.362</td>
<td>0.205</td>
<td>-1.049</td>
<td>-1.278</td>
<td>-0.166</td>
<td>-0.092</td>
<td>-0.354</td>
</tr>
</tbody>
</table>

**Locational Gini**

<p>| | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal weights</td>
<td>0.8461</td>
<td>0.8460</td>
<td>0.8460</td>
<td>0.8460</td>
<td>0.8460</td>
<td>0.8457</td>
<td>0.8457</td>
<td>0.8457</td>
<td>0.8455</td>
<td>0.8460</td>
<td>0.8459</td>
</tr>
<tr>
<td>Population weight</td>
<td>0.1602</td>
<td>0.1604</td>
<td>0.1604</td>
<td>0.1605</td>
<td>0.1602</td>
<td>0.1581</td>
<td>0.1583</td>
<td>0.1563</td>
<td>0.1595</td>
<td>0.1597</td>
<td>0.1589</td>
</tr>
</tbody>
</table>

**CO2 Emissions (kg per type of vehicle)**

|                          |          |            |            |            |            |            |            |            |            |            |            |
|--------------------------|----------|------------|------------|------------|------------|------------|------------|------------|            |            |            |
| Trucks (in % change)     | -        | -0.042     | 0.084      | 0.139      | 0.042      | -0.042     | -0.014     | -0.097     | -0.014     | 0.125      | -0.028     |

**Qualitative indicators**

|                          |          |            |            |            |            |            |            |            |            |            |            |
|--------------------------|----------|------------|------------|------------|------------|------------|------------|------------|            |            |            |
| Political cost           | Low      | Low        | Low        | Low        | High       | High       | High       | High       | High       | High       | High       |
| Financing cost           | High     | High       | High       | High       | Low        | Low        | Low        | Low        | Low        | Low        | Low        |
Commuting time and GRP growth

Baseline

Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
Scenario 7
Scenario 8
Scenario 9
Scenario 10

Average commuting time (min)
RMSP GRP (% change)
Mode shifts and CO$_2$ emissions

- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5
- Scenario 6
- Scenario 7
- Scenario 8
- Scenario 9
- Scenario 10

CO$_2$ emissions (% change)
Transit trips (% in total)

More rail

Baseline

Scenario 6
Scenario 7
Scenario 8
Scenario 9
Scenario 10
Scenario 5

CO$_2$ emissions (% change)
Summary of impacts on equity and efficiency indicators
Key messages (1)

Need to consider both internal and external interactions of the urban system – metropolitan issue

- Network effects: actions by neighbors (e.g. commuting trips) reinforce the consequences of a seemingly local phenomenon
- Economic effects are not only local – economic impacts spread through production and income linkages

Understand potential trade-offs – multidimensional analysis

Coordination of investments and national and local policies of urban development – avoid contradictions

Financing issues – who pays the bill?
“Food for thought” – Number of cars in SPMR

Frota de automóveis - Região Metropolitana de São Paulo (2001 a 2012)

Fonte: Elaborado pelo Observatório das Metrópoles com dados do DENATRAN
“Food for thought” – São Paulo 2016 elections

% votes for Haddad 2012

% votes for Haddad 2016

% households with car(s) 2000

% households with car(s) 2010
São Paulo 2016 elections

Difference in votes for Haddad 2012-16

Difference in households with car(s) 2000-10
Key messages (2)

How to address the commitments undertaken by the City of São Paulo in 2015, in Paris, to reduce GHG emissions?

**Composition** of the transportation matrix (extensive margin):

- Transit trips > Individual trips
- Rail > Roads
- Active trips (local reach) > > >

**Intensity** and emission factors (intensive margin):

- Low emission vehicles (alternatives to fossil fuels)
- Renovation of the bus fleet (electric vehicles)
Key messages (3)

“Compact”

- Reduce distance between firms (jobs) and workers (residents)

- Incentives to **co-location** of firms and workers through zoning decisions and planning of land use

- Problems of incentives design!