INVESTMENTS NEEDS FOR TRANSPORT INFRASTRUCTURES ALONG LOW CARBON PATHWAYS

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CONTEXT
Transport sector and infrastructures

- ‘Immobile capital’ (Prud’homme 2004)
- Long lifetime (Prud’homme 2004)
- ‘Lumpy’ investments (Lecocq et al, 2014)
- Increasing returns (Driscoll, 2014)
A role to play in the sustainable development

Population and economic growth → Higher freight and passenger activity

- 23% of energy-related CO2 emissions (IEA, 2012a)
- Highest GHG emissions growth since 1970 (IEA, 2012)

Balancing mobility demand

Increasing stocks and maintenance

Infrastructures

Mitigation

- Modal shift (Henao, 2015)
- Lock-in effect (Guivarch et al, 2011)
Chronic underinvestments

“The engineers estimated the cost of bringing America’s infrastructure to a state of good by 2020 at $3.6 trillion, of which only about 55 percent has been committed.” (ASCE, 2013)

“...the transport infrastructure gap in Latin America will once again increase, which could seriously limit the total volume traded” (Campos & Gaya, 2009)

“Years of chronic underinvestment in critical areas such as transportation [...] are now catching up with countries around the world.” (McKinsey, 2013)

→ Tension exacerbated or released?
Research questions and gaps addressed

**Investments needs under low carbon pathway?**

- Impact of climate policy?
- Regional heterogeneity?
- Determinants?

- Geographical scope
- Horizon term
- Only construction costs -> Underestimation?
- Climate policies
- Figures in cumulative terms + relative to GDP
- Exploring uncertainties
- Determinants? → sensitivity analysis
METHODOLOGY

1. Construction of socio-economic scenarios
2. Quantifying ‘ex-post’ investments needs
The IMACLIM-R model (Waisman et al, 2013)

- Hybrid model: CGE + bottom up modules
- Recursive dynamic architecture
- 12 sectors, 12 regions → 5 regions (ASIA, CIS, LAM, OECD, MAF)
- Second best worlds: myopic, imperfections

**Passenger:**
- Mobility services in utility function of households
- Time and budget constraints
- Modes: Personal vehicles, Air, Public transport, Non motorized

**Freight:**
- Leontief I/O coefficients
- Terrestrial, maritime, air
Exploring uncertainties

<table>
<thead>
<tr>
<th>Uncertainties considered (parameters set)</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth drivers</td>
<td>SSP₁, SSP₂, SSP₃</td>
</tr>
<tr>
<td><strong>Mitigation challenges</strong>: FF reserves, energy intensity, low carbon-tech development</td>
<td>SSP₁ (Low) or SSP₃ (High)</td>
</tr>
<tr>
<td><strong>Transport activity</strong> (affluence): mobility needs</td>
<td>Past trend or decrease</td>
</tr>
<tr>
<td><strong>Transport structure</strong>: mode shares, car occupancy</td>
<td>Individual or Shared-Mobility</td>
</tr>
<tr>
<td><strong>Transport intensity</strong>: energy efficiency</td>
<td>Low or High</td>
</tr>
<tr>
<td><strong>Transport Fuel</strong>: availability of alternatives</td>
<td>Low or High</td>
</tr>
</tbody>
</table>

→ 96 baselines scenarios
→ 3 climates policies studied: Baselines, Low mitigation ambitions, High mitigation ambitions

→ 288 transport activity scenarios with outputs: GDP, CO₂ emissions, pkm, tkm
Climate policies in Imaclim-R
METHODOLOGY

1. Construction socio-economic scenarios
2. Quantifying ‘ex-post’ the investments needs
Investments needs module

• Dissagregation of mobility scenarios
• Aggregation on the different infrastructures
• Calculation of infrastructure needs
• Associated costs
Investments needs module

+ Dissagregation of mobility scenarios
  • *Passenger*: car, air, public transport -> (BRT, train, bus, HSR)
  • *Freight*: terrestrial -> (train and truck)

• Aggregation on the different infrastructures

• Calculation of infrastructure needs Associated costs
Investments needs module

+ Dissagregated of mobility scenarios

+ Aggregation on the different infrastructures
  • Calibration of initial stocks
  • Rail: pkm+tkm per track.km
  • Road: vkm per paved lane.km
  • BRT lanes: pkm per trunk.km
  • HSR: pkm on track.km

• Calculation of infrastructure needs

• Associated costs
Investments needs module

+ Dissagregation of mobility scenarios
+ Aggregation on the different infrastructures
+ Calculation of infrastructure needs
  • Target of infrastructure occupancy on the long term (2050 or 2080). Linear evolution
  • Difference between existing stock and necessary capacity
  • Constraints on infrastructures density
• Associated costs
Investments needs module

+ Dissagregation of mobility scenarios
+ Aggregation on the different infrastructures
+ Calculation of infrastructure needs

+ Associated costs
  • New builts, upgrade, O&M (Dulac, 2013)
  • Airports: fixed cost per passenger unit
Uncertainties on parameters

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<td><strong>Mode shares</strong> (land freight and public transport)</td>
<td>Constant, Modal shift 2</td>
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</table>

- 5% of bus mobility as BRT (Dulac, 2013)
- Freight in 2050: 60% rail and 40% road (UIC, 2016)
- Passenger in 2050: 40% rail of public transport in 2050 (IEA, 2012)
Uncertainties on parameters

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<tr>
<td>Target of road occupancy (thousand vkm/lane.km)</td>
<td>600, 900</td>
</tr>
<tr>
<td>Target of rail occupancy (millions pkm+tkm/track.km)</td>
<td>5, 30</td>
</tr>
</tbody>
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Litterature in 2011
- **Road**: from 200 (India) to 1100 (Latin America) according to Dulac (2013);
- **Rail**: from 3 (EU27) to 35 (China)

Model calibration in 2015

<table>
<thead>
<tr>
<th>ASIA</th>
<th>CIS</th>
<th>LAM</th>
<th>MAF</th>
<th>OECD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road occupancy</td>
<td>200</td>
<td>300</td>
<td>1500</td>
<td>900</td>
</tr>
<tr>
<td>Rail occupancy</td>
<td>20</td>
<td>25</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>
# Uncertainties on parameters

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<tr>
<td><strong>Target of road occupancy</strong> (thousand vkm/lane.km)</td>
<td>600, 900</td>
<td>2</td>
</tr>
<tr>
<td><strong>Target of rail occupancy</strong> (millions pkm+tkm/track.km)</td>
<td>5, 30</td>
<td>2</td>
</tr>
<tr>
<td><strong>Year to reach occupancy target</strong></td>
<td>2050, 2080</td>
<td>2</td>
</tr>
<tr>
<td><strong>Road unit costs</strong>: evolution until 2080</td>
<td>Constant, +50%, -50% 3</td>
<td></td>
</tr>
<tr>
<td><strong>Rail unit costs</strong>: evolution until 2080</td>
<td>Constant, +50%, -50% 3</td>
<td></td>
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288 transport activity scenarios X 144 -> 41472 investments needs quantifications
RESULTS
Effects of LC policy on investments

Comparison of cumulative investment needs between mitigation scenarios and their corresponding baselines
Contribution of each infrastructure type
Drivers of investments reduction

Global passenger activity over time

Global freight activity over time
Drivers of investments reduction

- Transport activity decrease (freight and passenger)
- Mode shift to lower carbon modes

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2050</th>
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<tr>
<td></td>
<td></td>
<td>Baseline</td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td></td>
</tr>
<tr>
<td>ASIA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal Vehicle</td>
<td>24%</td>
<td>37%</td>
</tr>
<tr>
<td>Air</td>
<td>1%</td>
<td>3%</td>
</tr>
<tr>
<td>Public transport</td>
<td>40%</td>
<td>49%</td>
</tr>
<tr>
<td>Non Motorized</td>
<td>35%</td>
<td>11%</td>
</tr>
<tr>
<td>CIS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal Vehicle</td>
<td>64%</td>
<td>68%</td>
</tr>
<tr>
<td>Air</td>
<td>2%</td>
<td>8%</td>
</tr>
<tr>
<td>Public transport</td>
<td>23%</td>
<td>20%</td>
</tr>
<tr>
<td>Non Motorized</td>
<td>11%</td>
<td>4%</td>
</tr>
<tr>
<td>MAF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal Vehicle</td>
<td>31%</td>
<td>43%</td>
</tr>
<tr>
<td>Air</td>
<td>2%</td>
<td>5%</td>
</tr>
<tr>
<td>Public transport</td>
<td>42%</td>
<td>40%</td>
</tr>
<tr>
<td>Non Motorized</td>
<td>25%</td>
<td>12%</td>
</tr>
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</table>
Historical values of investments

Historical annual investments on transport infrastructures (rail, road and airports) - median (solid line) and 10th and 90th percentile (dashed lines) - Data aggregated by the authors from OECD (2017) and World Bank (2017) for 45 countries
Regional investments under HMA scenarios
Global sensitivity analysis with Sobol Method

Sobol method global sensitivity (Saltelli, 2008) analysis for the investments needs relative to GDP. Filled nodes represent the first-order indices and rings the total-order indices. Lines represent second-order indices arising from interactions between inputs. Width of lines indicates the second-order indices. Only the second-order indices greater than 5% of total variance are represented.
Global sensitivity analysis (Sobol)

Rail occupancy in 2015

- CIS: 25 millions tkm+pkm/track.km
- LAM: 6 millions tkm +pkm/track.km

Sobol method global sensitivity analysis for the investments needs relative to GDP.
Main Conclusions

• Cumulative investments needs in transport infrastructures reduced under climate policies compared to BAU
  -> Global, Regional, Robust to uncertainties
  -> Induced by transport activity reductions and modal shift
• Heterogeneity between regions under LC pathways
• Rail occupancy target is a influencing determinant
  → Irrealism vs strategy to avoid high investments
Limitations

• Results depend on model structure and parameters alternatives
• Calibration of initial infrastructures → lack of data, inconsistency
• Feedback effect of investments on GDP
• Benefits as damages avoided not included

Implications

• Decrease could compensate additional investments along LC pathway
• Optimization of rail infrastructure as a strategy?
  • Local conditions
  • Types of levers
Bibliography

• ASCE, 2013. 2013 report Card for America’s Infrastructure


