Hacia sistemas sustentables de movilidad urbana en el siglo 21: principios fundamentales y ejemplos

Programa de Capacitación para Jóvenes Profesionales
en Planeamiento, Regulación y Gestión Pública
del Transporte Urbano Metropolitano

Noveno Seminario de Actualización

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I. Metropolitan Mobility: Five Fundamental Principles

II. Sustainable Metropolitan Mobility: A Carbon Imperative?
- Mobility = *f* (Built Environment)?
- $CO2_{urban\ mobility}$ = *f* (BE) in a developing city?
- Examples: Santiago (Chile) and Jinan (China)
- Implications

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I. Metropolitan Mobility: Five Fundamental Principles

- **1. The Three I's (Information, Intelligence, Integration)**
- **2. Sustainability**
- **3. Multi-Scale (from local to global)**
- **4. Practical Innovation**
- **5. Education**

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1. The Three I's: Integration

- **Modes**
- **Purposes**, or end uses
- **Hardwares and softwares**
- **Disciplines**
- **Analytic approaches**
- **Institutions and sectors**

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1. The Three I's: Information

deployment of advanced communications and mobility technologies

generation of data with potential applications to the transportation sector

Range of Applications:

Real-time (Operational) → *Strategic*

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1. The Three I's: Information

- **Main challenge:** *right* information into the *right* hands at the *right* time for the *right* purposes:
  - User decisions
    - *before* and *during* travel
  - Provider decisions
    - deployment; when travel is taking place
    - **accurate pricing** of the assets
  - Planning decisions
    - what to provide, when, and where

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1. The Three I's: Intelligence

Challenges

- Deploying data sources for improved tactical, operational, and strategic purposes
- Information overload risk
- Privacy, data ownership (and thus permitted use) and transparency (including for accountability).

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1. The Three I's: Intelligence

- Data-collection *deployment*
  - e.g., smart phones, and the like, for improved travel and activity surveys
- Data *mining* to extract higher level knowledge
- Data and computing to improve our *predictive* capabilities
  - short-, medium-, and long-term predictions
  - knowing what the system will do and how we can make it do it better.

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1. The Three I's: Examples

CityMotion (MIT Portugal Program)

- *Information* (data) from public/private sectors
- Large source of heterogenous data, compiled and "fused" by a university consortium to demonstrate the power of the fusion.
- Example: short-term traffic prediction tool using DynaMIT on Brisa toll-road

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1. The Three I's: Examples

Singapore MIT Alliance for Research and Technology: **Future Mobility** program:

1. information and communication technologies
2. advanced integrated microsimulation models (short-, medium-, long-term)
3. the policy, planning, institutional and financial framework necessary to use the information and knowledge ***wisely***

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2. Sustainability

- What are we trying to *sustain*?
  - Accessibility
- Sustainable Mobility:

Maintaining the capability to provide *non-declining* accessibility over time

- Accessibility = *superior* good.
  - Much (most?) of the developing world is accessibility *poor*
  - Improving accessibility, sustainably, is a fundamental development imperative

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2. Sustainability

- How do we know we are moving in the right direction?

The development and deployment of "metrics that matter"

- Standardized, meaningful, scale-able and operational performance measures
  - reflecting accessibility (in its multiple dimensions)
  - ***and*** life-cycle-based effects
    - based on full-cost accounting principles, etc., on the other.

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3. Multi-Scale

- From Neighborhood to Metropolis to Regions
- Global Perspective Necessary
- North ←→South
  - E.g., bus rapid transit (BRT)

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4. Innovation

- Requires entrepreneursip
  - Again, South → North Lessons…
- Technology-enhanced/enabled
  - Combine “high”/“low” techs (Paris’ Velib)
  - capitalize on intermediate mode potential
  - revolutionize financial/incentive system

“Distributed” knowledge infrastructures

  - Dynamic infrastructure management
  - Mobility brokers
- Barriers: digital divide; privacy concerns; data ownership; ‘opting out’

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5. Education

- Need for new trans-disciplinary capabilities
- Cooperative Educational Models
- Next generation of professionals and ongoing capacity-building
- PCTU is a great example

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5. Education

3 Universities: IST-Lisboa, U. Coimbra, Porto

3 Domains: Management & Finance, Engineering, Policy & Regulation

3 Themes: Transportation systems, International context, Business models

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In Sum: Metropolitan Mobility for 21st Century

Information → Intelligence → Integration → Sustainability

Multi-scale

collaborative networks and partnerships practical

↓

Innovations

and

Education

of the next generation of global leaders

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II. Sustainable Metropolitan Mobility

A carbon imperative in the developing world?

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Accessibility
how do we "get" it?

Contributing Factors	Effect on Accessibility (all else equal)
Mobility	Improved with more links, faster or cheaper service
Spatial distribution of "opportunities"	Improved if proximity of opportunities is increased
Individual (personal/firm) characteristics	Improved with physical, mental, economic ability to take advantage of opportunities
Quality of opportunities	Improved with more, or better, opportunities within same distance/time
Information and communications technologies (ICTs)	Improved with more, more rapid, and more 'realistic' connections

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Why focus on developing urban areas?

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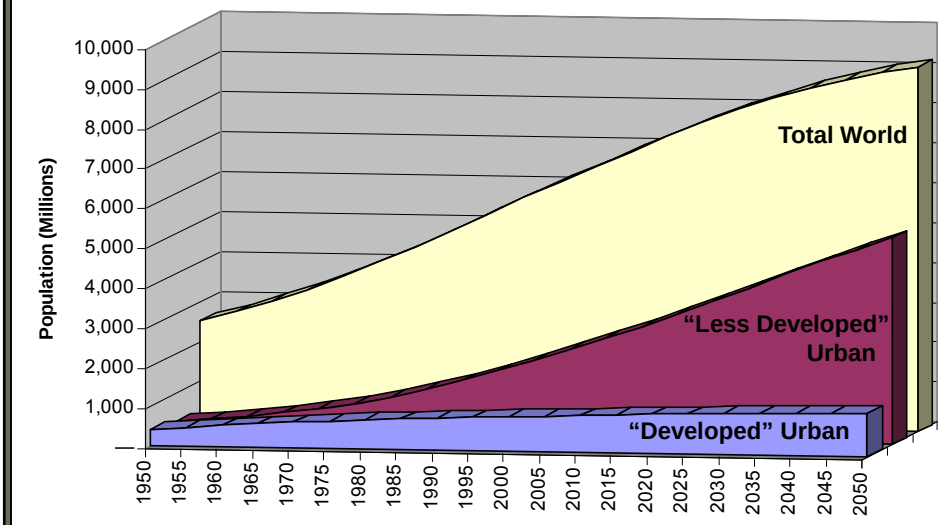
Global Population and Urbanization Prospects



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The Urbanizing Developing World…the current paradigm does not scale…

By 2030

~2 billion new residents

X

~3,000 vkm/person/year

=

~6 trillion additional vehicle kms/yr

=

~600 billion additional liters of gasoline/yr

or

~1.4 billion tonnes of CO2 annually

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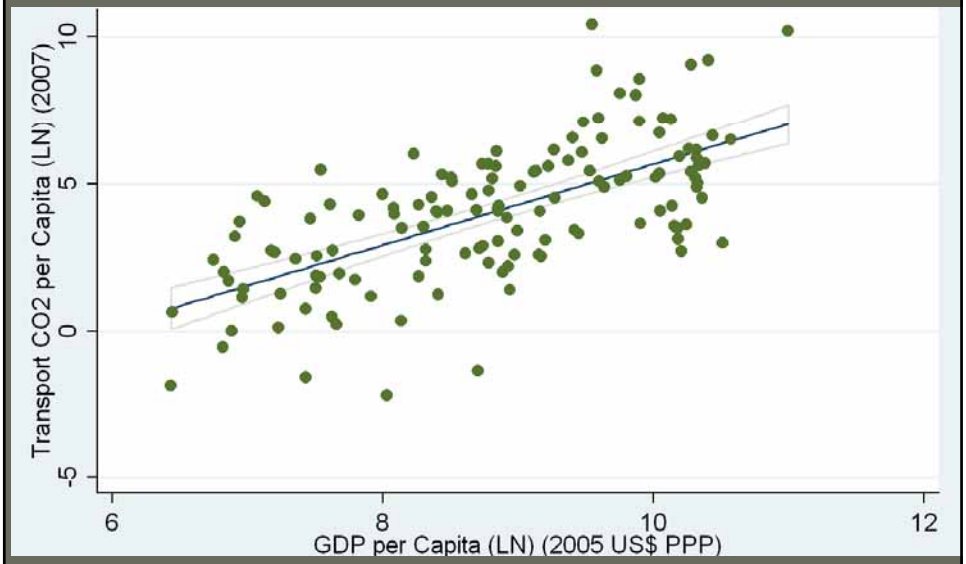
National-Level Data



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National-Level Data

- GDP per capita explains “only” about 40% of variation
  - suggests an elasticity of about 1 (0.95; 0.66-1.22)
- Density, primate city, national rail and road network, and exports explain another 30%

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Urban Transport GHGs

=

Fuel Choice (grams / liter)
• Fuel Type • Engine Type • Vehicle Age • Temperature• Altitude
• Built Environment? • Etc.

x

Fuel Intensity (liters / pkm)
• Engine Type • Vehicle Load • Vehicle Age • Congestion Levels
• Capacity Mix • Built Environment • Etc.

x

Mode Share (% pkm)
• Income • Motorization • Infrastructure • Service Provision
• Relative Costs • Built Environment • Etc.

x

Activities (pkm = trips x kms)
• Population • Demographics • Income • Economy
• Built Environment • Etc.

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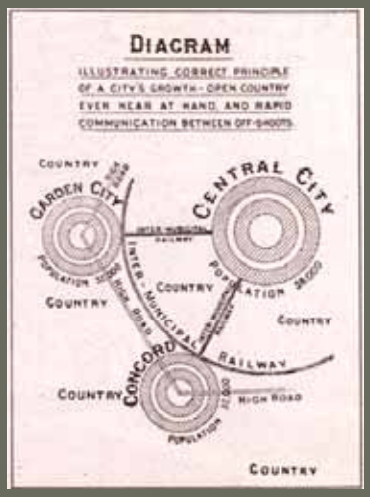
Travel Behavior (TB) = *f* (BE)?

Something new?



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Travel Behavior (TB) = *f* (BE)?

Theoretically, ambiguous **net** effects

- BE influences *net* utility for user
  - Disutility: costs of travel (including perceived)
  - Utility: potential activity destinations
- Example, If BE → $TT_i\downarrow$, then *i* might
  a) Increase activity time,
  b) Choose alternative (more-preferred) destinations,
  c) Schedule additional non-home activities.
- b) and c) would result in increased total travel,
  - consistent with the idea of constant travel time budgets
  - (empirical challenge: typically available travel survey data…)

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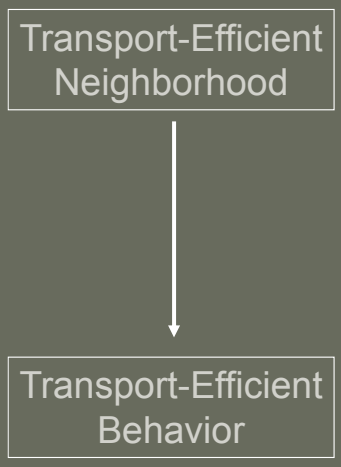
TB = *f* (BE)?
Unclear pathways of effects



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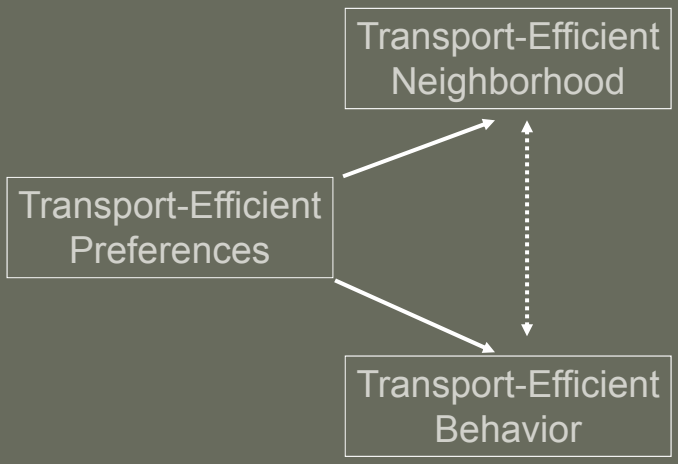

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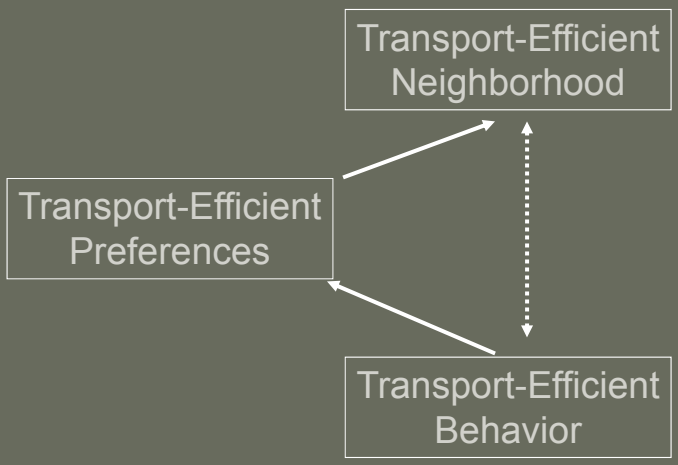

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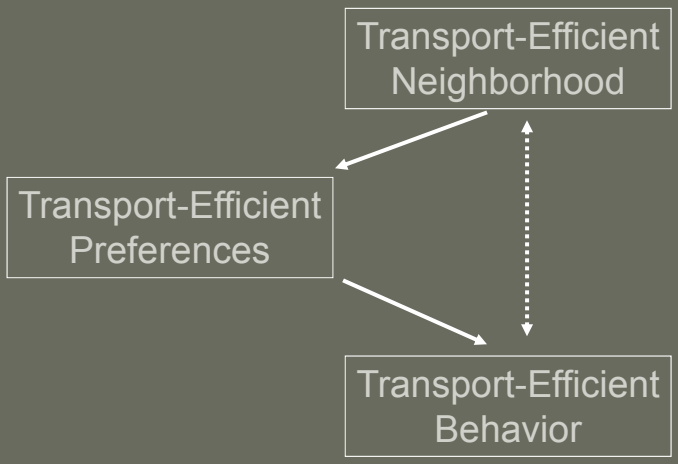

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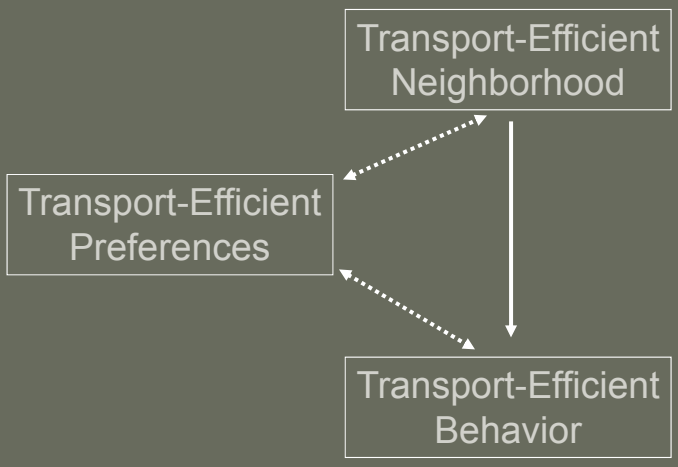

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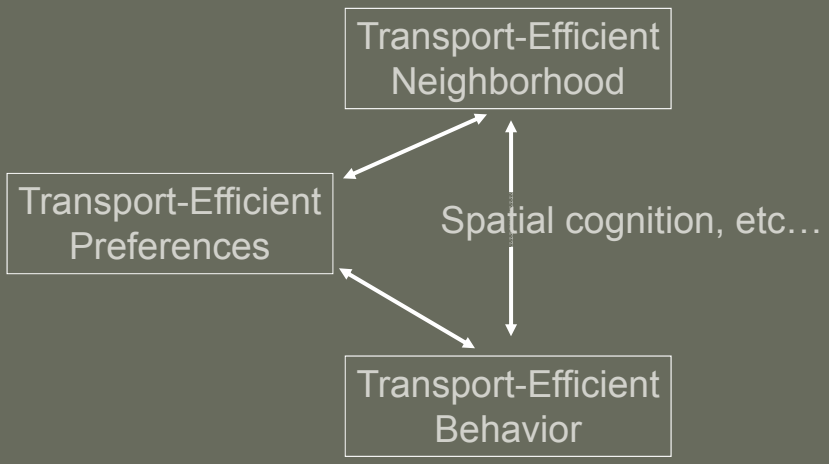

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TB = *f* (BE)? Empirical Evidence

Challenges to generalizability include variations in:

- Scale of analysis
- Types of BE measures used
- Travel behavior data used
- Analytical approaches and control variables employed; and,
- Ultimate outcomes measured
  - e.g., trip frequencies, mode choices, distances, etc.

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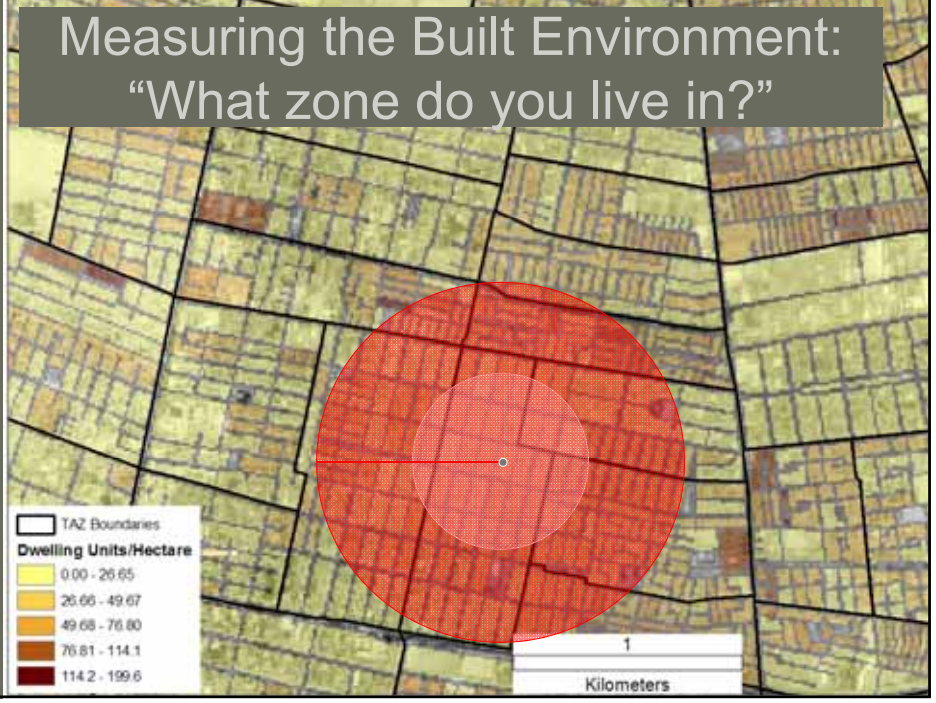
Measuring the Built Environment: "What zone do you live in?"



TB = *f* (BE)? Empirical Approaches

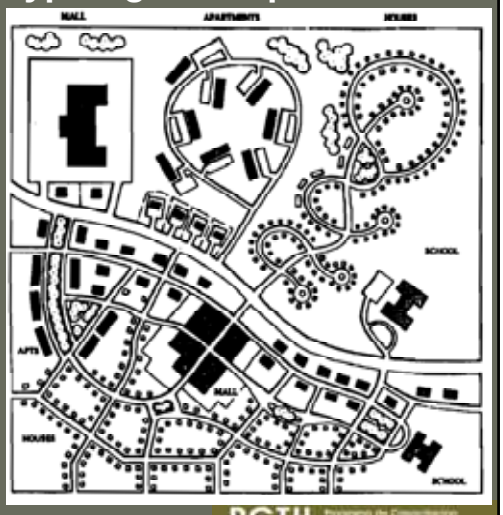
"Vector" representation of the BE, e.g.:

- Density
- Diversity
- Design
- Relative Location

➢ But, these variables are, in reality, limited

➢ And, maybe the "whole > ΣParts"?

Typological Representation



Empirical Precedents: USA?

- Doubling of future development densities
  - Up to 60 mn new DUs by 2030
  - 1-8% reduction in CO2 versus BAU

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Examples from two (very?) different developing urban contexts

Santiago Chile

- data provided by SECTRA
- analysis with G. Hunter (MCP)

Jinan, China

- travel data collected by Shandong Univ.
- analysis with Y. Jiang (MCP/MST)

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A few stats

Characteristic	Santiago	Jinan
Density (persons/hectare)	61	65
Urban pop. (mn)	~5.5	~4
Avg HH Income (US$)	$9K (2001)	$5.5K (2006)
Avg Home Size (m^2)	71	68
HH Auto Own Rate	42% (2001)	31% (2006)
Public Mode Share	33%	16%
Auto Mode Share	22% (2006)	14% (2004)
GDP/Capita (AAGR 90-08)	4%	9%
Gini Coefficient	52	42
Gasoline/Capita (liters)	149	45
US$ Gas/Diesel per ltr (2004)	109/86	69/61

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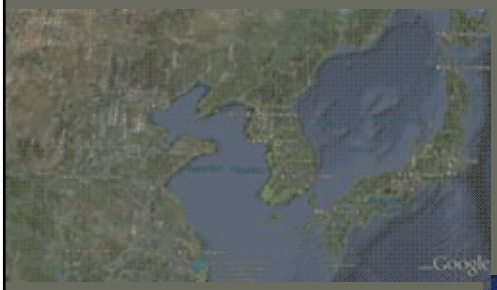
Examples from two (very?) different developing urban contexts



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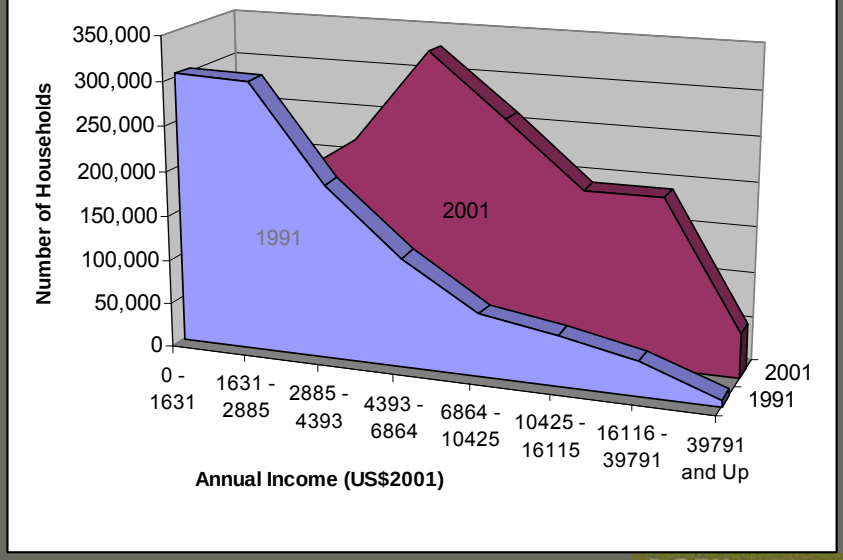
Santiago's Emerging Middle Class



Sources: Derived from SECTRA, 1992; 2002

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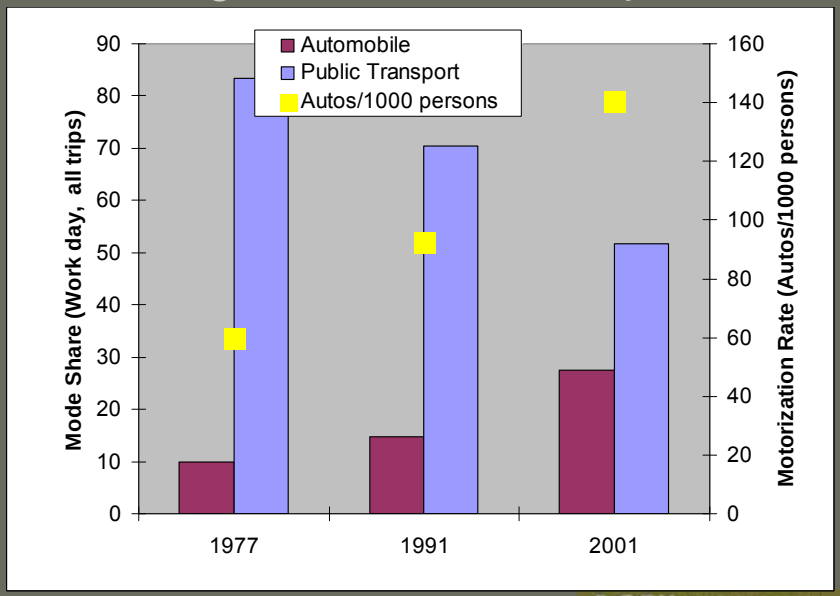
Santiago's Auto Ownership & Use



Source: derived from SECTRA, 2002

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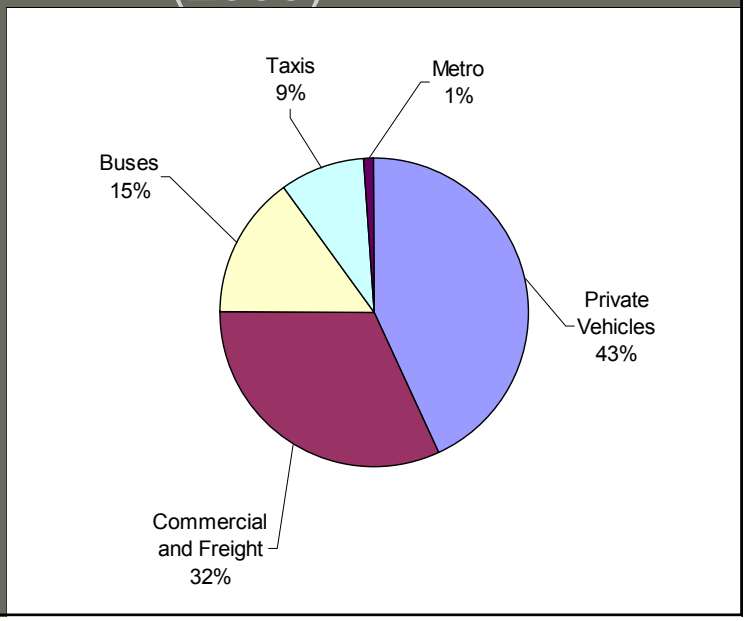
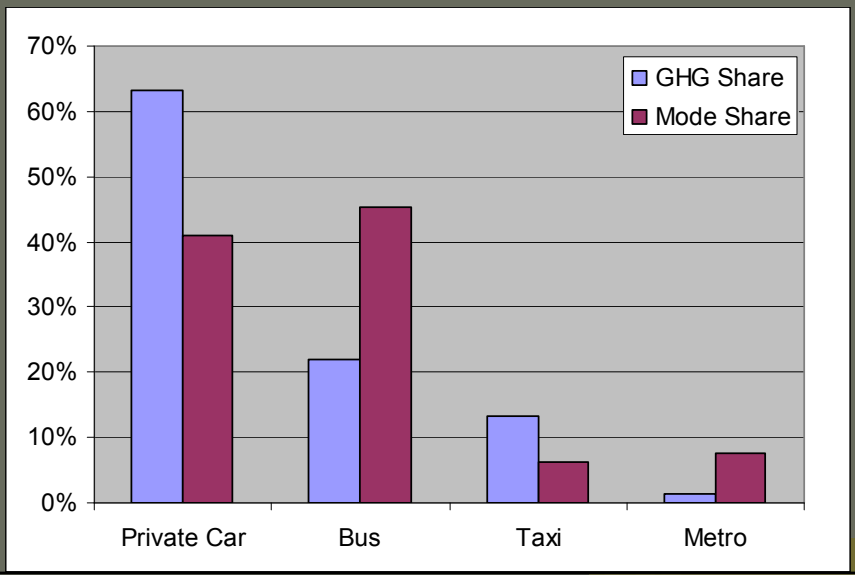
Santiago's Transport CO_2 Emissions (2000)



Sources: Univ. de Chile, 2002; Metro 2002; DICTUC, 2004

Santiago's Passenger Transport: Mode Share vs. GHG Share



Santiago: Previous Analysis

HH Motor Vehicle Ownership (# vehicles) =
f (HH Characteristics, Urban Form, Urban Design)

Selection bias and endogeneity

Motor Vehicle Use (VKM/day) =
f (# vehicles, HH characteristics, urban form, urban design)

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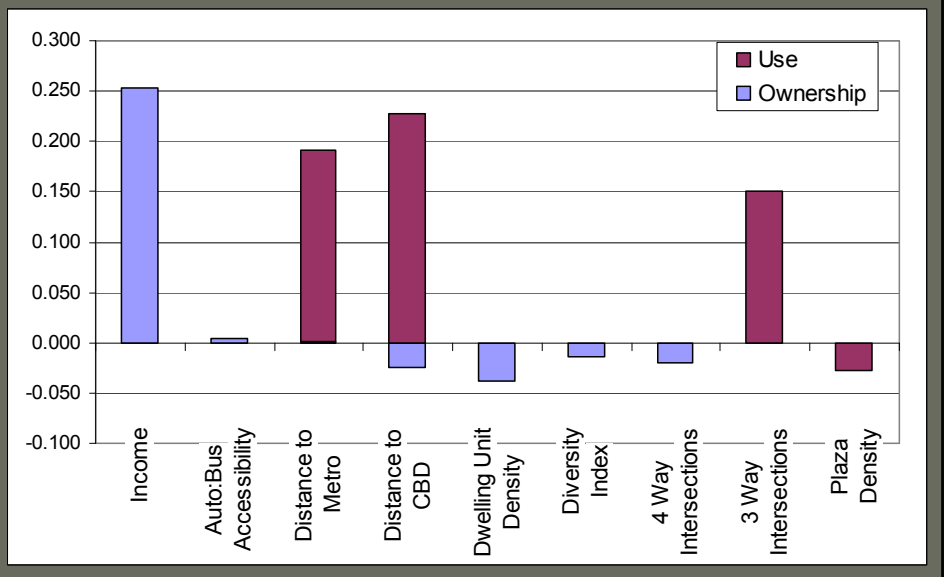
Results: Elasticities of Auto VKT



Zegras, 2010.

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But, what about CO2, accounting for all travel modes?

- Distance to CBD effect falls
  - Reduced auto VKT still requires travel by other (motorized) modes
- Metro effect disappears
  - Strange result given Metro's relative "CO2-cleanliness"
- Combined effect of land use mix, CBD distance, residential density, street layout (share 4-way intersections) = income effect
  - Elasticity of CO2 = ~0.37
- Models still being refined
  - Including for joint effects and underlying modal substitutions.

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Examples from two (very?) different developing urban contexts

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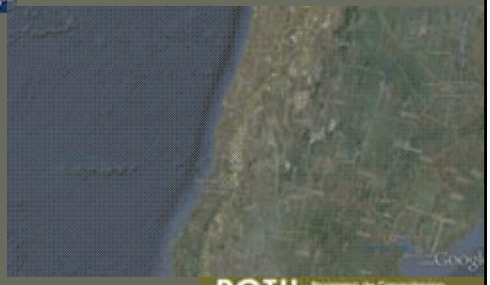

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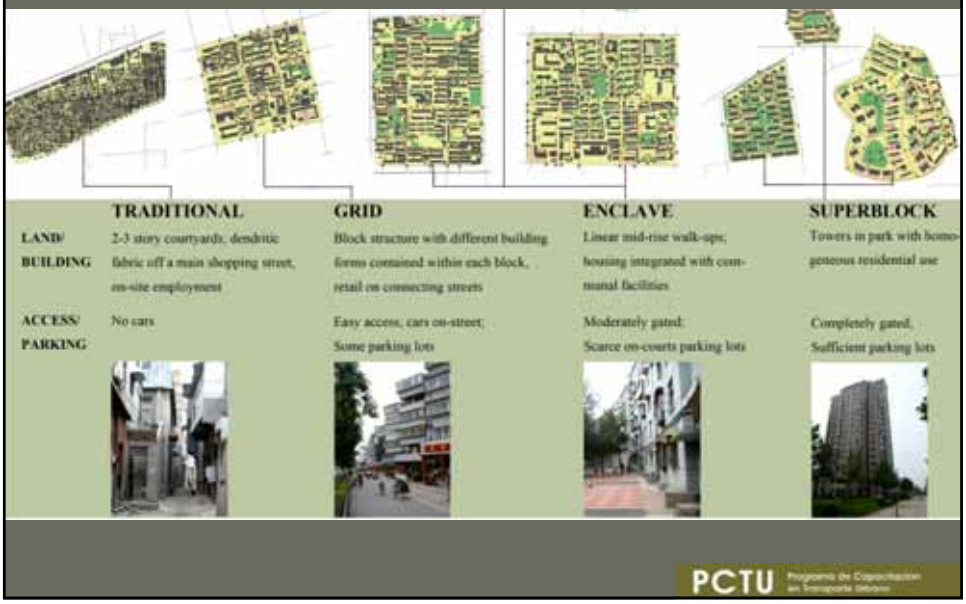
Neighborhood Typologies in Jinan



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Typologies: Basic Characteristics

	Traditional	Grid	Enclave	Superblock
Parking (lots/100 HHs)	0	4	4	37
Entry Interval Dist.(m)	218	107	148	730
Green Coverage	0%	12%	17%	31%
Land Use Mix	0.23	0.32	0.37	0.07
Building Function Mix	0.33	0.34	0.38	0.04
Population Density (persons/km2)	34,000	37,500	43,500	46,000
Household Density (households/km2)	12,500	19,000	19,500	16,000
FAR	1.2	1.7	1.8	2.0
Average Building Height (floors)	2.2	5.5	5.3	10.1

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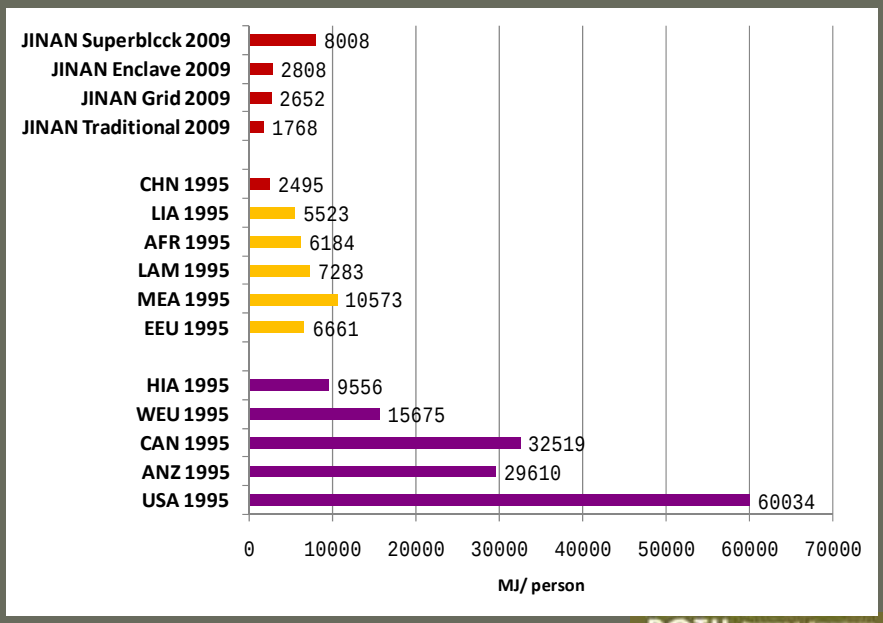
Transportation Energy: MJ/Person



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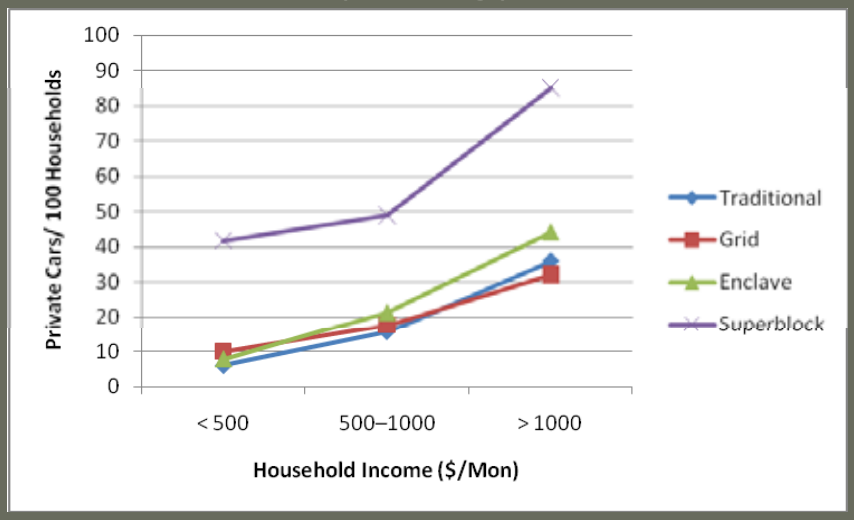
Vehicle Ownership: Income and Typology



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Jinan: Analytical Approach

- 9 neighborhoods, 4 typologies
  - Approx. 300 HHs per neighborhood
- For the moment, only MJ (not CO2…yet)
- Again, 2-stage models
  - Vehicle ownership
  - Total transportation use

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Jinan Analysis Results

Variable	Effect on Auto Own	Effect on Energy Use via		Combined Effect on Energy (MJ/HH/Wk)
		Car Own.	All Veh. Use	
Traditional	-24%	-75	-55	-130
Grid	-30%	-86	-30	-116
Enclave	-31%	-86	-21	-107
2x Dist. to City Center	-8%	-18	+42	+23
On BRT Corridor	-4%	-6	+29	+22
Double Income	+12%	+31	+15	+46
Have Company Car	-	-	+562	+562
Own Motorcycle	-8%	-14	+76	+61
Own E-Bike	-10%	-13	-23	-36
Own Bike	-10%	-10	-29	-40

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$CO2_{urban\ transport} = f\ (BE)$?

- Is the BE associated with lower urban transportation CO2 emissions?
  - YES, with combined effects at least as strong as the income effect
  - And, interestingly, income effect is closely comparable across the 2 settings examined
    - Jinan: 0.35-0.48 (MJ); Santiago: 0.37
    - How does this compare to the global national averages?

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$CO2_{urban\ transport} = f\ (BE)$?

- Does the BE *cause* lower urban transportation CO2 emissions?
  - Cannot say based on our analyses
- What about effects on *total* transportation emissions?

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$CO2_{urban\ transport}$ = *f* (BE), so?

- Is BE the most cost-effective mitigation measure?
  - Again, cannot tell from our analyses
  - But, technology alone will not likely get us where we need to be by 2030…
- What about the carbon offsets market?
  - Behaviorally based efforts
  - Integrated models have too much uncertainty
  - "Statistics-based" approaches have not yet convinced the relevant powers (CDM Board)

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$CO2_{urban\ transport}$ = *f* (BE), so?

- Has transportation been held (unfairly) to a higher standard?
  - E.g., uncertainties, "leakage", etc.
  - Some quantification challenges are not inherent to transport alone

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$CO2_{urban\ transport}$ *quo vadis*?

- Challenge too large for the current project-based offset approach?
  - Across-ASIF suite of interventions may be most necessary
- Sectoral and/or programmatic CDM still face fundamental challenges
  - Baseline establishment, leakage, verification, additionality, accountability, etc.
- Advanced ICTs *could* help in modeling, monitoring & verification
  - And additional behavioral change

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$CO2_{urban\ transport}$ *quo vadis*?

- Carbon tax: where for art thou?

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