

Evolving Metropolitan Structures & their Impact on Personal Mobility

Towards a Research Proposal

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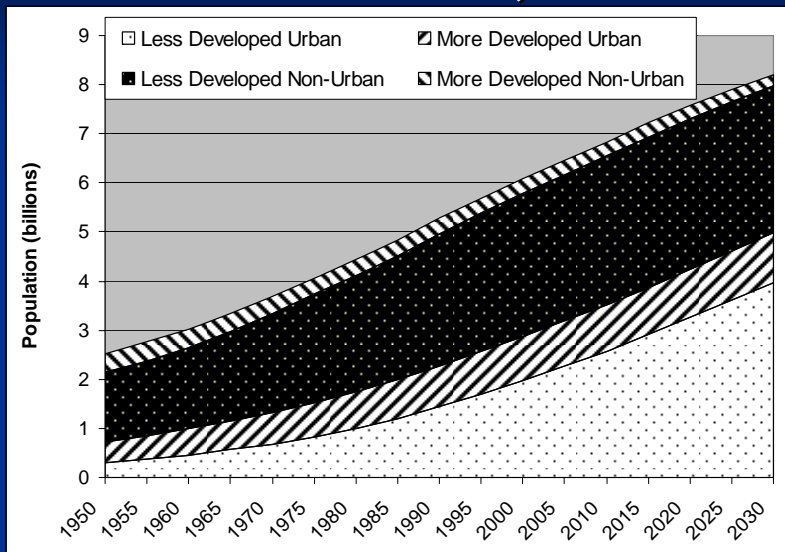
- Transportation & Energy
 - Justifying a Metropolitan Focus
- Metropolitan Structure and Travel Behavior
 - Approaches and Evidence (from a city)
- Metropolitan Mobility & Energy Futures
 - Towards a Proposal

Transportation & Energy: Will Technology Provide the “Solution”?

Heywood et al (2003) modeling US light duty fleet

- *combined* strategy
 - slower annual growth in new vehicle sales,
 - a decline in light duty truck market share,
 - a 50 percent market share of hybrid vehicles,
 - and *no growth* in VKT
- would produce:
 - 2000-2010: 13 percent increase in fuel consumption
 - 2020: Return to 2000 levels
 - 2030: reduction to 1970 levels by 2030.
- “sobering overall conclusion”
 - technology improvements *and* reductions in travel growth are critical

World Demographic and Urbanization Projections



Source: UN, 2004.

The Urbanizing Developing World

- Urban population in developing world will *double* by 2030
 - 95% of net global population growth
 - 1.94 billion additional people
 - (developed world urban population doubled during 2nd half of 20th Century – adding ½ billion people)
- By 2015, 19 of 23 of the world's cities with >10 million people by 2015

What does this growth mean?

- A back of the envelope mind exercise; assume:
 - 3,000 private vehicle kms/capita in developing cities by 2030¹
 - 10 liters/km private vehicle average fuel consumption
- = ~6 trillion additional private vkms/year by 2030
- = ~600 billion additional liters of gasoline per year (53% greater than today)
- = ~1.9 billion annual tonnes of GHGs (lifecycle CO₂-equivalents)

¹ Today: 1848 developing Asia; 4519 Europe; 11,155 US (Kenworthy & Laube, 1999).

The Developing World: Mobility “Poor”

- From 2000-2050, increases in per capita vehicle kilometers traveled (VKT)
 - OECD: 0.2 to 0.8 percent per year;
 - China: 6 percent per year;
 - India: 5 percent per year;
 - Latin America: 3 percent per year
- Still, by 2050 North America will have 3 times the VKT per capita than Latin America (compared to 11 times today)

Derived from IEA (2004).

Urban Decentralization

	pop/sq km (1960)	pop/sq km (1990)	% chg. (1960-1990)
Tokyo	8,565	7,097	-17%
New York	2,878	2,086	-28%
Paris	6,860	4,614	-33%
London	6,539	4,232	-35%
Detroit	1,970	1,275	-35%
San Francisco-Oakland	1,640	1,602	-2%
Washington	2,046	1,373	-33%
Melbourne	2,028	1,491	-26%
Hamburg	6,827	3,982	-42%
Vienna	9,141	6,830	-25%
Brisbane	2,095	978	-53%
Copenhagen	4,952	3,467	-30%
Amsterdam	9,973	5,591	-44%
Zurich	5,998	4,708	-22%
Frankfurt	8,722	4,661	-47%

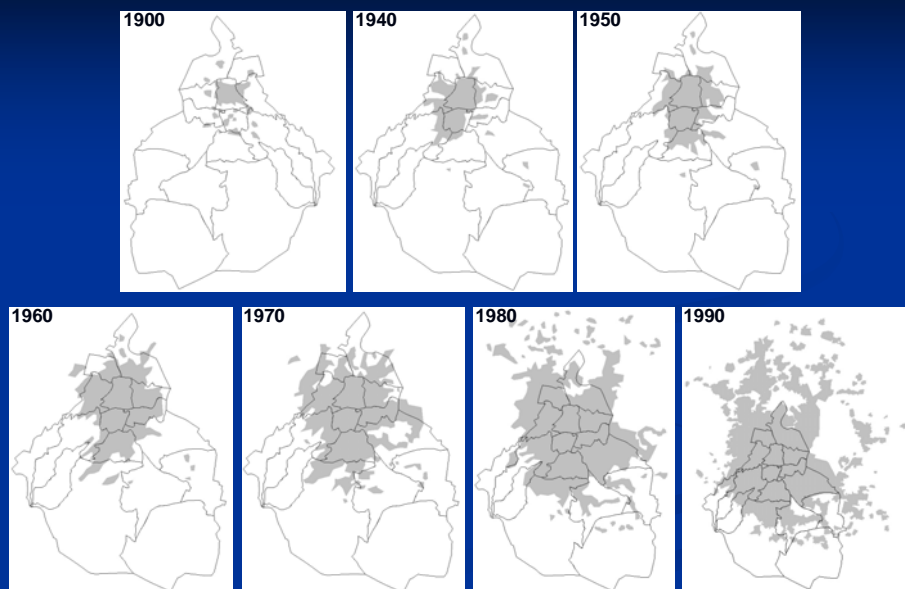
Will the developing world follow suit?

WBCSD, 2001.

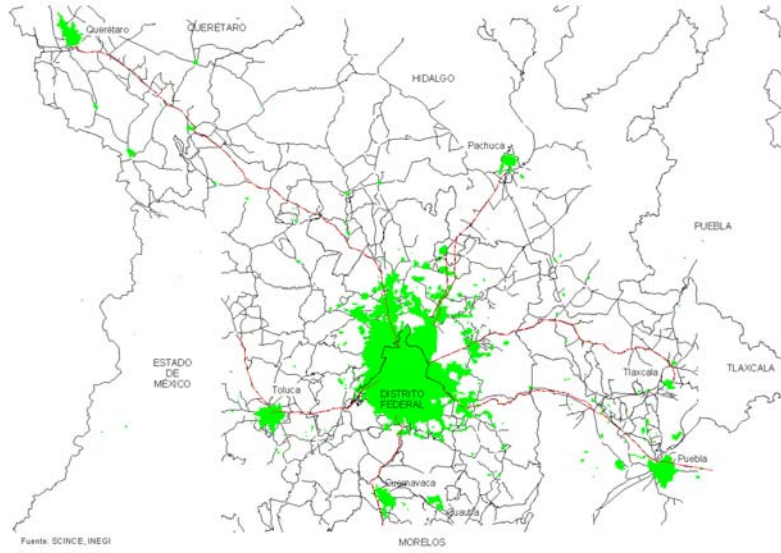
Urban Decentralization

- Shanghai
 - 1990-2000: 2 mn people moved from center to periphery
 - Center city density 32 times higher than new peripheral developments
- Mumbai
 - 1981-2001: Suburbs accounted for 50% of population growth
- Mexico City
 - 1940-1995: the city expands at 1.5 times the population growth rate
 - Grows from 13 political jurisdictions to 54

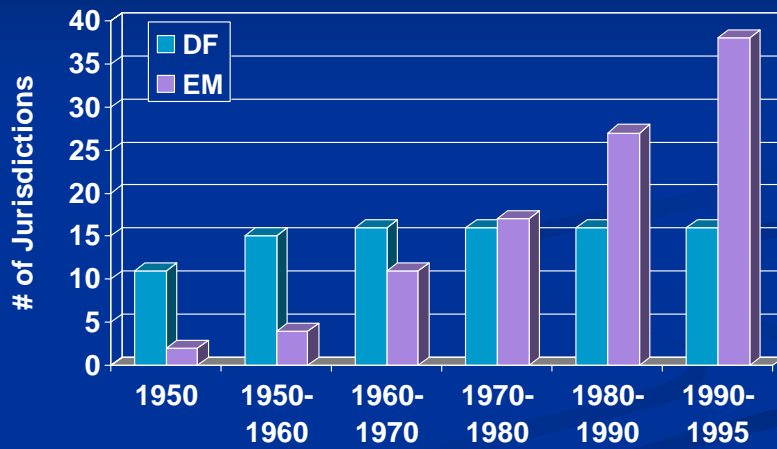
Mexico City: Physical Expansion



The Mexico City “Megalopolis”



Mexico City Metro Area Political Jurisdictions



Urban Mobility: The Primary Drivers

A. Urbanization

(Urban population growth)

+

B. Decentralization

(Urban outgrowth, "sprawl")

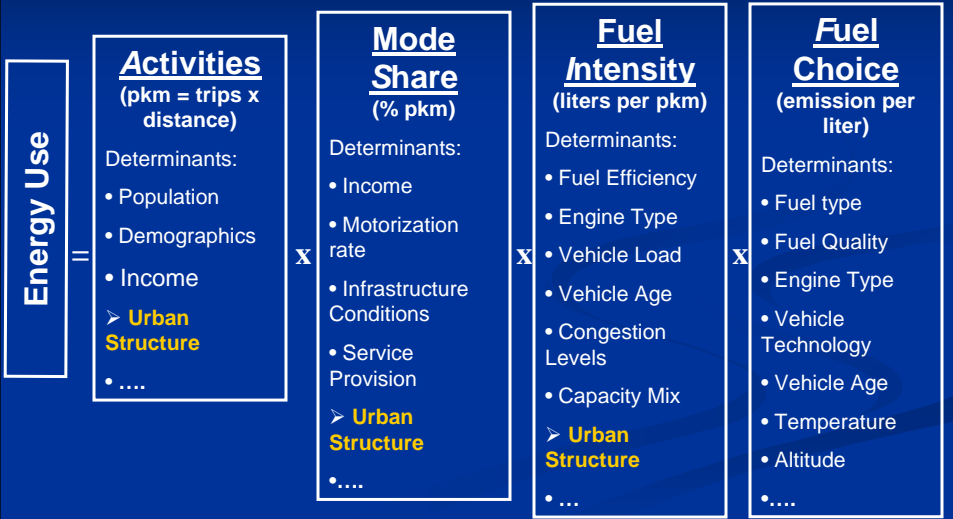
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C. Income Growth

=

More people making **more** motorized trips over **greater** distances

Transportation Energy Use Drivers



Sources: Based on Pargal & Heil, 2000; Schipper et al, 2001.

The Built Environment (BE) & Transportation: A Question of Scale

Analytical Scale	Physical Form	Example BE Indicators	BE Influences on Mobility, e.g.:
<u>Metropolitan</u>	Urban <i>Structure</i>	Overall City Size	Maximum intra-city travel distance
<u>Intra-Metropolitan</u> (“Meso”)	Urban <i>Form</i>	Activity Concentrations	Relative attractiveness of different areas of the city
<u>Micro Scale:</u> (neighborhood)	Urban <i>Design</i>	Local street configurations	Pedestrian attractiveness

Transport = f (BE): Fundamentally *Behavioral*

Urban Structure, Form, & Design

Density of Land Uses/Activities
Mixes of Land Uses/Activities
Design



Travel Demand

Relative Travel Cost: Changes in trip distances between Origins & Destinations
Relative Modal Costs: e.g., trip times
Relative Quality of Modes: e.g., safety/security



Behavior “Produced”

Changes in number/share of motorized/non-motorized modes
Changes in Travel Distances
Changes in Vehicle Occupancy

Transport = f (BE)?

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What does the evidence suggest?

- Generalizations difficult due to variations in:
 - analytical approaches,
 - spatial scales of analysis,
 - BE characteristics measured,
 - mobility outcome measured (trip rate, trip time, distance, mode, etc.)
 - data type, model specification, etc.

Transport = f (BE)?

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What does the evidence suggest?

- Nonetheless, a few generalizations possible:
 - Metropolitan-scale: total urban area, *ceteris paribus*, on total travel (e.g., Cameron et al, 2003)
 - Intra-Metropolitan scale: Poly-nucleation, distance to CBD, population density
 - Micro-Scale: local mixing and density has apparent some influence, effect on net travel indeterminate
- Impacts are, quite possibly, “different in every context”
(Handy, 1996)

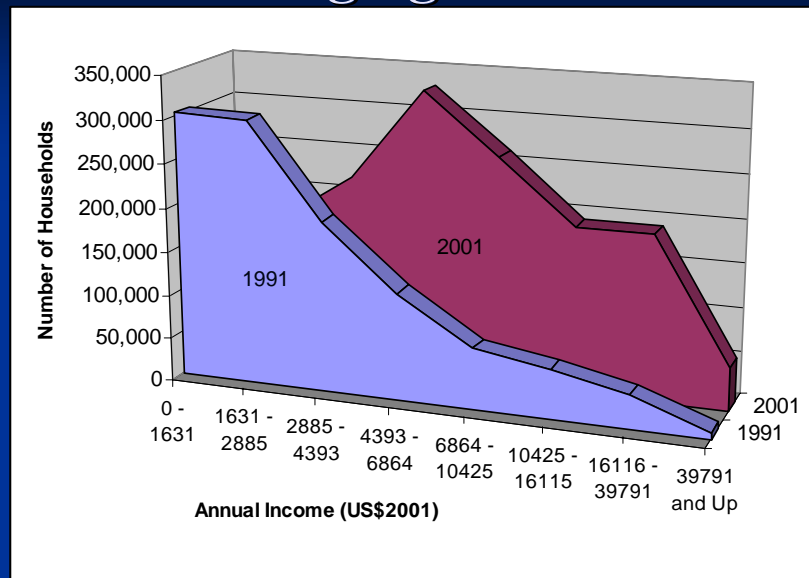
Evidence from a Latin American City

Santiago de Chile: A middle income Metropolis

Income Category	Number of Households	% of Total Households	Average HH Income (US\$2001)
High Income	85,226	5.6%	50,300
Medium Income	822,964	54.4%	11,250
Low Income	605,747	40.0%	3,070
All	1,513,937	100.0%	10,200

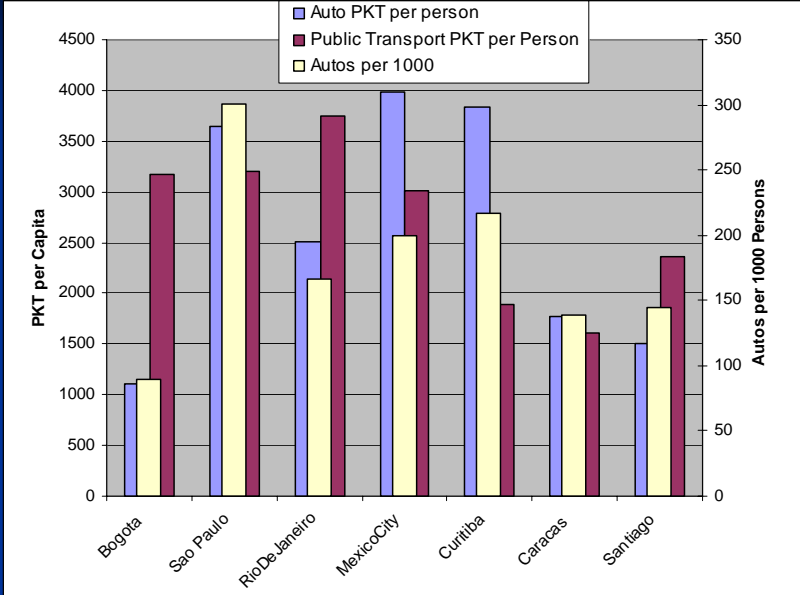
Source: Derived from SECTRA, 2002

The Emerging Middle Class



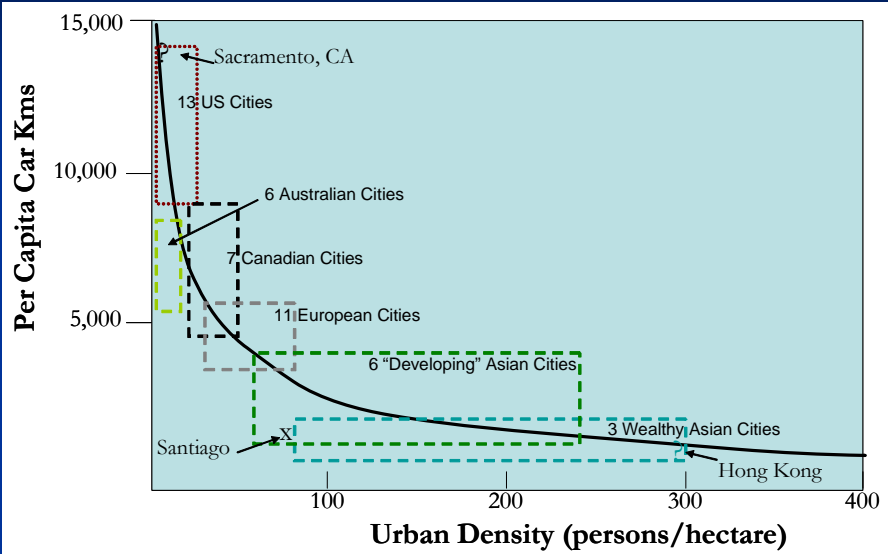
Sources: Derived from SECTRA, 1992; 2002

Santiago in Regional Context

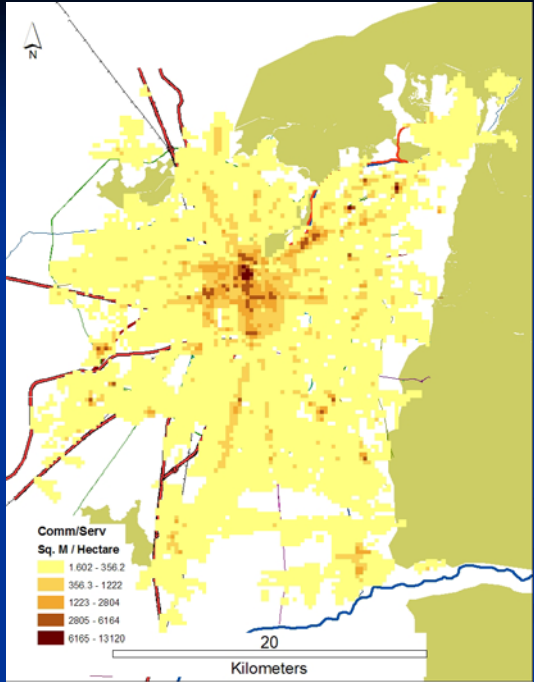
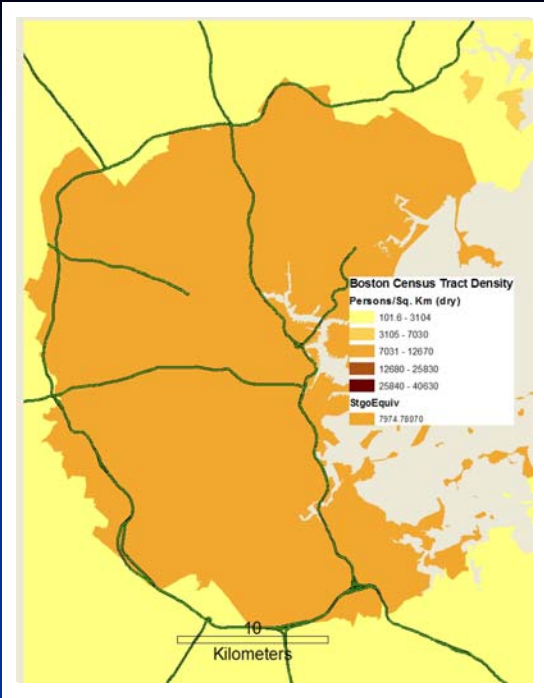


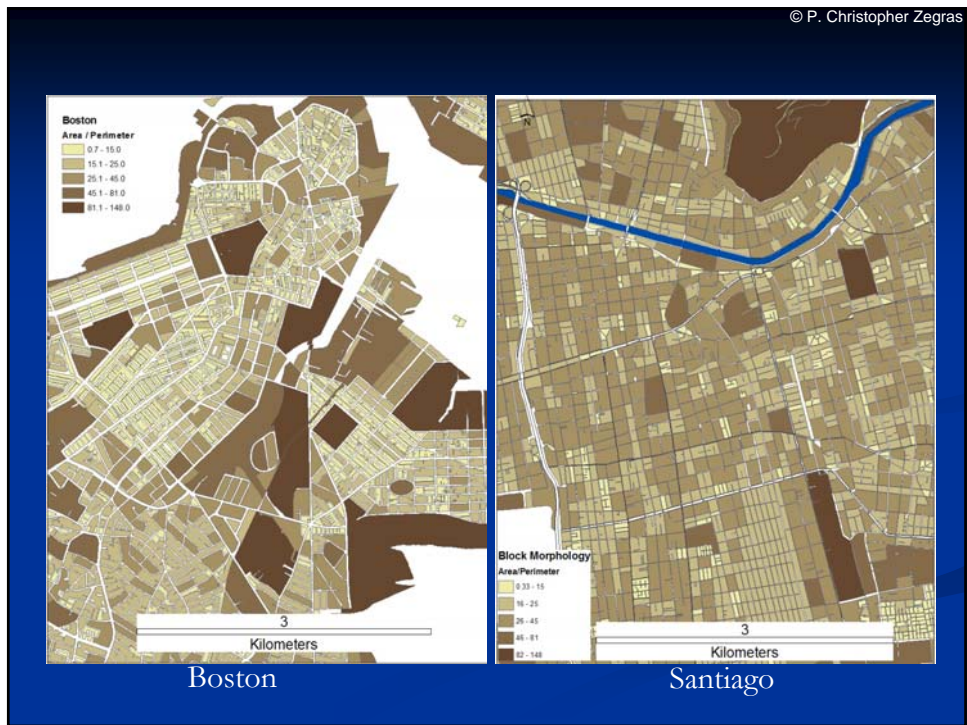
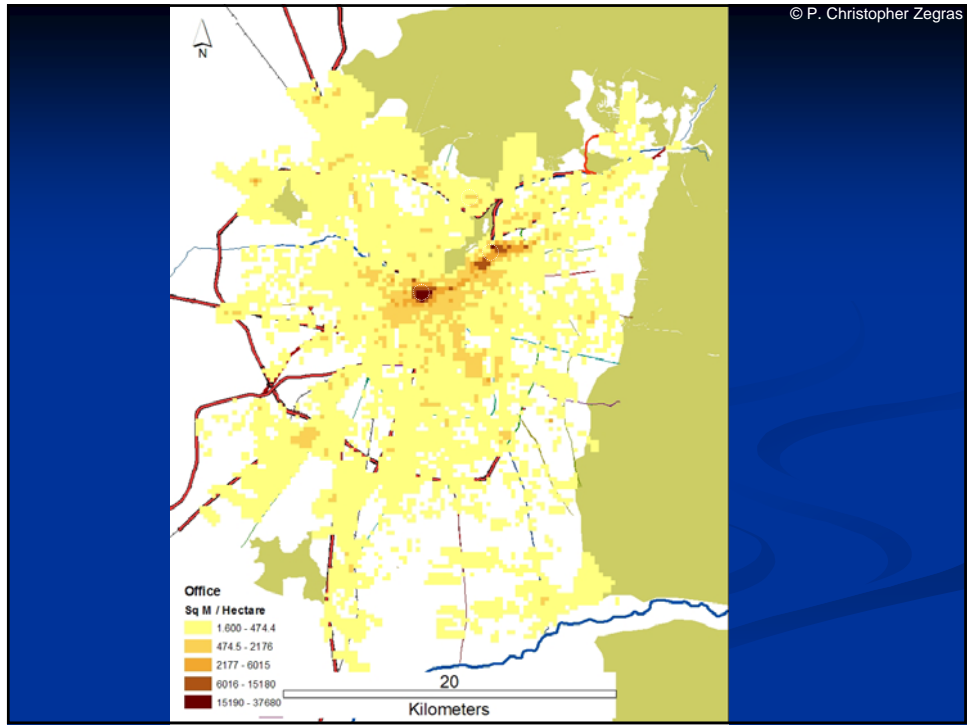
Source: UITP "Millennium Database" (except Santiago)

Metro Area Density & Travel: World



Source: Kenworthy & Laube (1999)





What Role of the Built Environment on the Motorization Process?

- Discrete choice model (multinomial logit) of household vehicle ownership
 - Decision to own: 0, 1, 2, 3+ vehicles in the home
 - HH Vehicle Ownership:
 - 0 Vehicles: 59% of HHs
 - 1 Vehicle: 32% of HHs
 - 2 Vehicles: 8% of HHs
 - 3+ Vehicles: 2% of HHs

HH Motor Vehicle Ownership Choice

Characteristic	Variable	Number of Vehicles		
		1	2	3
<i>HHs</i>	Household Income	+	++	++
	# Persons	+	++	-
	# Adults	-	n.a.	+
<i>Urban Form</i>	Auto:Bus Accessibility	+	++	++
	CBD Dist	n.a.	+	+
<i>Urban Design</i>	Apartment	-	--	---
	Diversity Index	n.a.	-	--
	Dwelling Unit Density	n.a.	-	--

n=14729. Rho-Square = 0.451. n.a.means variable was not significant for the relevant choice.
In all other cases, significance at $\geq 95\%$

Zegras, 2005.

What Implications for Metropolitan Structure, Form, Design?

Auto Ownership

- At least one vehicle seems a certainty as soon as income allows; some dampening effect from apartment living
- *Micro-Level* BE:
 - Dwelling unit density and land use mixing (diversity index) have the strongest effect of the BE variables on additional (i.e., after first) vehicle ownership
 - Apartment living also has a significant influence
 - No detectable effect related to street patterns, block morphology, intersection density
- *Meso-/Metro-Level* BE:
 - The “compact city” finds some support: distance to CBD and bus/auto accessibility effects

Zegras, 2005.

The Role of the Built Environment on Vehicle Use

- OLS model of total Household vehicle kilometers traveled
 - On day of survey
 - Distance derived from trip x,y coordinates and shortest path on road network
- $VKT = f(\text{HH Socio-demographics, Trip-Making, Urban Form, Urban Design})$

Zegras, 2005.

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Element	Variable	B	Stdzred	Sig.
Vehicles	Share "Green Auto"	3316	0.06	0.0070
	# Vehicles	7672	0.21	0.0000
	Avg. Veh. Age	-269	-0.07	0.0006
HHs	HH Income (US\$)	102	0.08	0.0004
	# Drivers License	1110	0.04	0.0336
Trips	# Trips	927	0.28	0.0000
	No Distance coded	-1514	-0.09	0.0000
	Normal Sat	-2709	-0.03	0.0098
	Normal Sunday	-6716	-0.09	0.0000
	Summer Sunday	-7374	-0.05	0.0000
Urban Form	Dist to CBD	0.59	0.11	0.0000
	Dist to Metro	0.61	0.07	0.0020
	Foothills	3363	0.04	0.0279
Urban Design	4-Way Int. per KM	-1651	-0.05	0.0006
	3-Way Int. per KM	468	0.03	0.0261
	Plaza Density	-17156	-0.02	0.0255
	Constant	-3743		0.13

Motor Vehicle Use Results

Dependent variable:
Total HH vehicle use
(measured in meters traveled)

R-Squared = .27;
N=4279.

Heteroskedasticity-Consistent Standard Errors used to Determine Significance

Zegras, 2005.

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What Implications for Metropolitan Structure, Form, Design?

Auto Usage

- *Micro-Level* BE
 - Local street network and public spaces (plazas) have some effect
- *Meso-Level* BE
 - Again some support for the "compact city" (CBD effects)
 - Increasing proximity to Metro.
 - Only 700,000 people (13% of Greater Santiago's current population) live within 1 km radius of existing stations (average walk to Metro is 400 m)
 - Auto-owning HHs within 1 km radius of existing stations, on average, travel ~2 kms less by auto than those living 4 kms from a station
- Most design influence seems to come via impacts (of, e.g., land use mix) on second or third vehicle ownership, thus use

Zegras, 2005.

City Restructuring: Energy Savings at What Cost?

Modeling Approach

1. A 3-Stage integrated travel demand model (generation, distribution, mode choice)
 - simulates transportation system equilibrium to predict how future travel patterns will evolve under different land use scenarios.
2. A land use model (bid-rent, urban equilibrium) model
 - calculates the subsidies that would be required to make households and firms locate according to the various scenarios.
 - makes all agents' interactions explicit (in their bid functions), including location externalities (e.g. neighborhood quality) and firms' agglomeration economies.

Donoso, Martínez, Zegras (2005)

City Restructuring: Energy Savings at What Cost?

Modeling Approach

- Considers the “full” set of relevant choices... except...
 - Route assignment
 - Weekend activity patterns
 - Trip-chaining
 - Freight impacts...

Donoso, Martínez, Zegras (2005)

Emissions (GHG) Reductions and Cost per Tonne

Scenario	Item	Year 7	Year 10	Year 14	Year 21
<i>Education</i>	Cumulative Tonnes (mns)	2.8	4.4	6.6	10.9
	Cost per Tonne	9	6	4	2
<i>Non-Residential</i>	Cumulative Tonnes (mns)	5.4	8.1	11.9	19.4
	Cost per Tonne	147	139	121	91
<i>Sub-Centers</i>	Cumulative Tonnes (mns)	8.6	13.6	20.7	34.6
	Cost per Tonne	921	848	724	538
<i>Pre-Optimal</i>	Cumulative Tonnes (mns)	12.7	21.1	33.2	56.5
	Cost per Tonne	2,930	2,989	2,645	2,014

Donoso, Martínez, Zegras, 2005.

Towards a Research Proposal

A Multi-Metropolitan Area Analysis

- Purpose:
 - explore the range of potential transportation (passenger and freight) energy pathways
- Possible Approach
 - (0) Looking “Back to the Future”
 - assessing past efforts to predict the future
 - (1) Understanding potential metropolitan mobility futures in a wide-range of contexts
 - (2) Identifying the more promising pathways (technological, behavioral, institutional) for reducing energy consumption in those contexts
 - (3) Developing feasible strategies for embarking on those pathways.

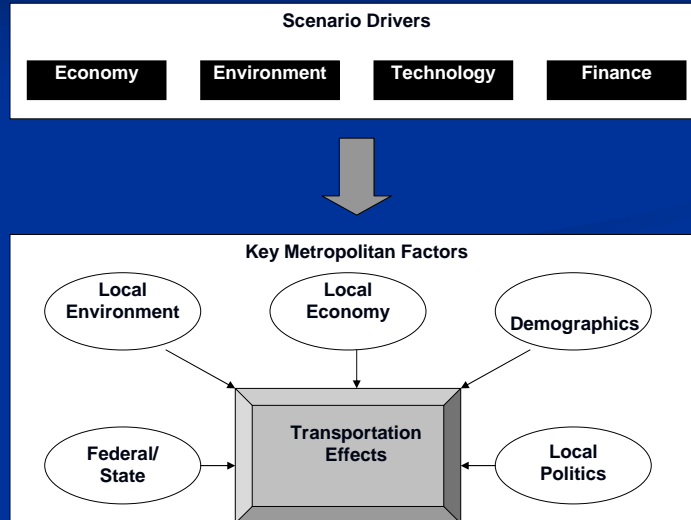
Challenges Towards a Proposal

- Meta-Framework for Analysis
 - Unified approach
 - But, flexible (e.g., re: data availability)
- Metro-area selection – “archetypes”, ideally representing, e.g.:
 - Megacities and secondary cities,
 - High and low motorization environments,
 - Varying rates of change
 - Cultural contexts
 - Regional contexts
- Practically, constrained by:
 - Existing relationships (relevant, reliable partners)
 - Data availability

Metro-Area Choice: Relevant Characteristics for “Archetypes”

- Factor analysis on *Millennium Database* yields dimensions of relevant variation:
 - (1) Motorization Degree; (2) NMT/Public Transportation; (3) Externalities; (4) Affordability; (5) Efficiency
- SESAME Project (EU), cluster analysis identifies:
 - (1) Car Cities; (2) Car & Walk Cities; (3) Public Transport Cities; (4) Public Transport & Walk Cities; (5) Bike Cities
- Pew Center for Climate Change suggests relevant factors:
 - (1) Authority; (2) Policy Environment; (3) Land Use Patterns; (4) Social Norms; (5) Interest Group Strength; (5) Infrastructure Precedents

A Scenario Platform?



Towards a Metropolitan Transportation Energy Pathways Project...

In summary

- Assess the broad range of future interventions that offer possibilities to influence medium- and long-term passenger and freight transportation demand, including:
 - vehicle technologies,
 - infrastructure supply and demand,
 - economic development,
 - human settlement patterns,
 - Combine technology and policy-oriented focuses,
 - across a range of *contexts*.

