Urban Transportation, Land Use, and the Environment in Latin America: A Case Study Approach

Lecture 11:

The Santiago Metropolitan Area

Transport System: Brief History

- Horse trams and steam trains (to San Bernardo and Puente Alto) by turn of Century
- By 1930s, city has one of most extensive electric tram networks in South America
  - 220 kms, 210 passengers/year
  - Dismantling begun in 1945
- By 1960s (first land regulatory plan)
  - Plans also laid for Metro system
  - Construction begun on ring road (Vespucio), Avenida Kennedy (East to Las Condes) and the PanAmerican Highway

Policy Context

- Urban Policy
  - Strongly influenced at national level
    - Specific policy interests fluctuating in time with politics
  - 1993 policy-formulation process recs:
    - Goals: decentralization; environment and quality of life; equity in access to goods and services; economic growth and modernization; more a balanced distribution of population and economic activity across the country (CED, et al., 1994).
    - Measures: capacity building; institutional improvement; strengthened role of local governments (Municipalities); improvement in regional planning instruments and processes; improvements in urban information systems; internalization of external costs, promoting the use of non-motorized transportation and shorter trips, densification and mixing of land uses, "sub-centers")
    - "Ideal" rhetoric, but, nothing formal still written…policy vacuum prevails

Policy Context

- Urban Transport Policy
  - Strongly influenced at national level
    - For long time, an ad hoc amalgam of activities at different government levels
  - Santiago reaches crisis by the 1970s, early 1980s SECTU, later SECTRA, is born
    - Develops, formalizes evaluation techniques, data collection, etc.
    - Technical, demand- and system-management perspective (engineering approach); little consideration to land use alternatives as management option
  - No formal "policy" exists, "rational" rhetoric disarticulated by different apparent "schools of thought" prevailing among institutions
    - The "infrastructure camp" v/s the "management camp"
    - Ultimately determined by who has the money?

Today's Transport Modes & Infrastructure

- Cars, Buses (*Micros*), Trucks Taxis, fixed route taxis (*colectivos*), Metro, Suburban Rail, Walk, Bike
- Approx. 4,700 kms of roadways
  - Plus, Vespucio Ring Road and the Pan American Highway
- Two Segregated Busways
  - 5 km segment and ~10 km stretch
- Differentiated and (in city center) segregated bus stops
- 3 Metro Lines: 40 kms, 51 stations, 68 trains, built at $1.6 billion (US$1999)
- Suburban Rail: 9 stations, 85 kms south to Rancagua

NMT Facilities

- Wide sidewalks and well-signaled pedestrian facilities increasingly common (especially in heavy commercial areas)
- Few bicycle facilities

Major Recent Projects in Greater Santiago

- Upgrade of Ring Road (Vespucio) in North, Northwest
- Overpass/underpass on Kennedy Highway to the East (Las Condes)
- Major Road upgrades in Southeastern suburbs
- Completion of Metro Line 5 to city center

Major Recent Projects in RM

- Completion of Route 78 (*Autopista del Sol*) to Port of San Antonio
- upgrade of Route 57 north to Los Andes (road to Argentina)
- upgrade of Route 68 west to Valparaiso

System Management

- UOCT (Operative Traffic Control Unit)
  - Traffic Light Operations (1600 intersections)
    - 80% on pre-established timing (traffic-count based); 16% dynamic control (SCOOT); 4% sensor-activated
- One-way streets during peak periods
- *La Restriccion* – vehicle restriction, similar to *Hoy no Circula,* in place since late 1980s.
  - Odd-even scheme implemented during pollution months
  - Initially, aimed to reduce on-street fleet by 20%
  - In 1993, cars with catalysts exempted
  - Currently in force 4 March to 31 December
    - Includes private cars, trucks, school buses, taxis, buses & trucks (during off peak periods) w/out advanced pollution control techs.
    - Currently reduces approx. 8% of cars on any given day
    - With higher pollution days, can be expanded.

System Management

- Using pollution as a force for "immediate actions" March – December:
  - 9 "*vias exclusivas*" for public transport
    - During AM Peak (7:30 – 10:00)
    - Three additional lanes and PM Peak added during pollution episodes
  - "Reversible Lanes" for Private Transport
    - Primarily during AM peak

Bus System History

- 1970s: Strong state intervention
  - Private operators, but all key variables (frequency, routes, fares) under government control
- 1979-1982: Complete deregulation
  - Part of government neo-liberal reforms
  - Fares, routes, operations
  - Problems already evidenced
- 1982-1988: Partial re-regulation
  - Over routes (particularly in the center city) and vehicle age
- 1988: Complete deregulation, again
  - Only controls over vehicle quality via inspections

Bus System by 1990

- Results are in
  - Positives: Supply and service area expansion, frequency increase
    - 1978-1985: Bus and Minibus fleet grew 50% and 75% (respectively)
  - Negatives: Decline in occupancy rates (50%), cartel control of fares and entry (self-regulating "mafia"), old vehicles, poor maintenance, devastating public image (in face of motorization)
    - By 1991: 13,500 vehicles, average age of 14 years
    - Bus oversupply estimated at 4,000 vehicles, consuming $24.4 million per year in excess fuel, 10% excess of PM emissions
    - 10-fold increase in bus fare relative to minimum family wage (77-87)

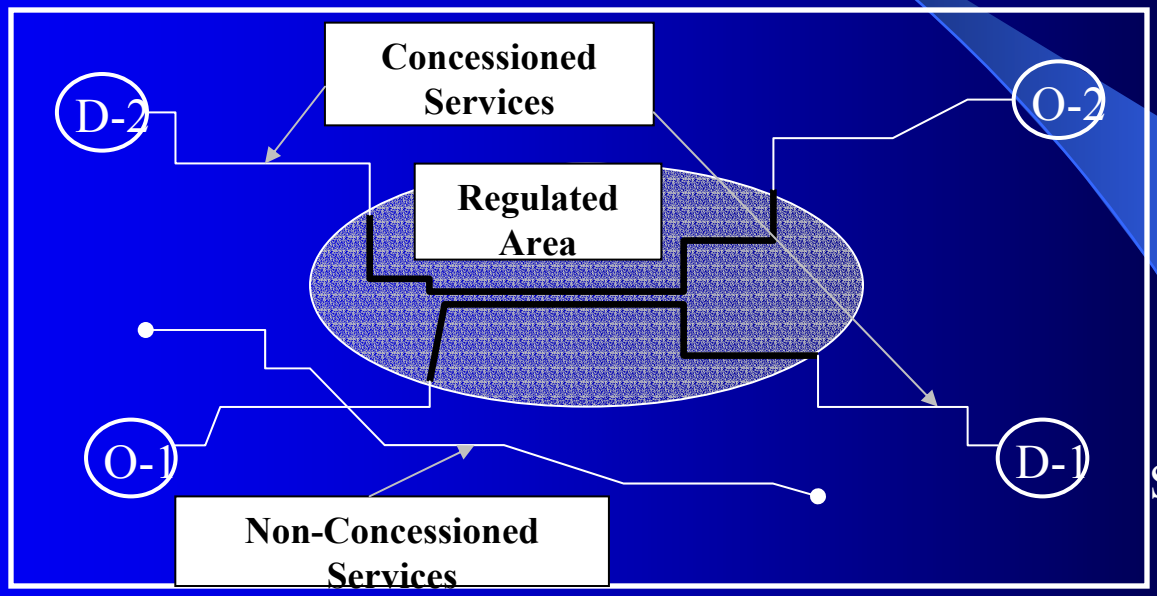
Early 1990s: The Process of Bus System Reform

The Early 1990s – process of reform

- Purchase of oldest vehicles on street
  - 2,600 vehicles at cost of $14 million
- 18-year old age limit established
  - Implying further retirement of 2,000 vehicles (91-94)
- Emissions standards
  - From 1990 to 94: Permitted exhaust opacity levels, 32% ⇒ 9%
  - 1993: all new engines, EPA-91
  - 1996: EPA-94

1990 – The Legal Foundation

- Concessioning (public bidding) of routes where congestion, pollution, and/or safety concerns exist



Source: Dourthe et al., 2000.

– Service Terminals (Os and Ds) established

– Routes outside "regulated area" are flexible

– Route and frequency criteria must be met within the "regulated area"

Concession Basis

- **Routes and Frequencies** – Bid must present a fleet consistent with these requirements
- **Vehicle Age** – lower average age, greater points
  - 10-year limit for traditional buses; 14-year-old limit for buses meeting EPA standard
- **Vehicle Capacity** – higher avg. capacity, more points
- **Formalization of the operators** – with clearly defined legal representative
- **Fares** – in bid, operator chooses from four possible fares, lower far, greater points
  - A formula for fare increases set: a weighted sum that includes the variation in fuel, tire, labor, US & Brazilian exchange rate & other costs (adjustment indices come from independent agency – INE)

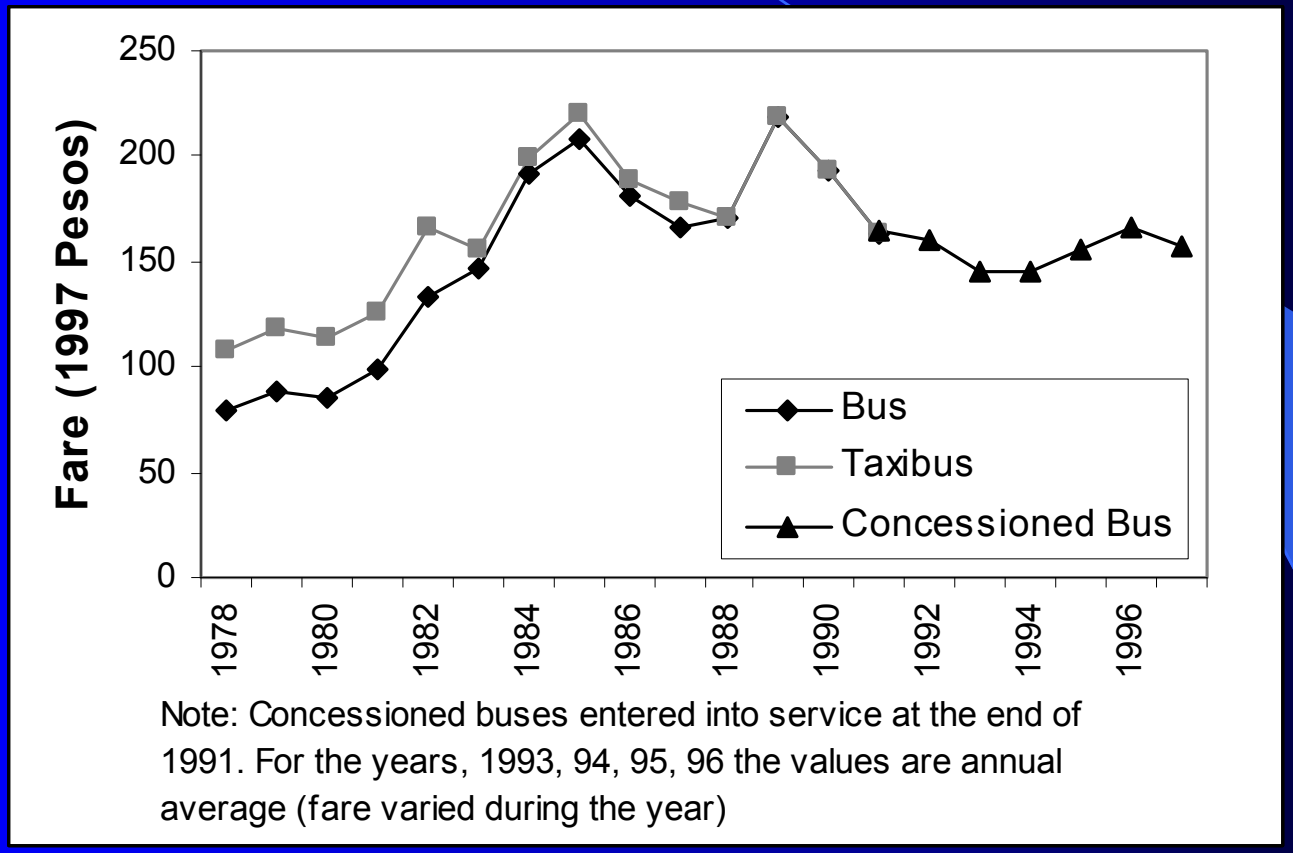
Concession Stages

- 1992 – 36 month term
  - Automatically extendable if certain conditions met, re: vehicle technology and driver remuneration
- 1998 – 60 month term
  - With automatic 6 month extension by Ministry possible
  - Additional incentives to improve quality of service
    - Operators meeting a minimum percentage of fleet with EPA technology, with automatic transmission, A/C, and minimum fleet % using CNG had right to:
      - increase fare by 10% after 1st year,
      - in the fourth year, extend by an additional five years the term of the concession
  - Due to the variation in demand (peak, off-peak, holidays, vacation periods) – allow predetermined frequency adjustments
  - Authority maintains right to alter service requirements based on demand changes over time

Results

- **"Regulated Area" now 270 km^2**
- **Reduction and modernization of the fleet**
  - 1992: 13,550 vehicles, avg. age 14
  - 2000: 9,000 vehicles, avg. age 4
  - Investment of US$ 500 million by private sector
- **Improved Service Quality**
  - Travel times (despite slightly increased wait time), comfort, cleanliness, safety, uniformity of service and information
- **Pollution**. > one-half buses comply with EPA-91/94
- **Modernization of buses operators**
- **Fare Stabilization and De-politicization**
  - Fares remained roughly constant since 1991 (~US$0.30)

Evolution in Bus Fares



Note: Concessioned buses entered into service at the end of 1991. For the years, 1993, 94, 95, 96 the values are annual average (fare varied during the year)

Source: Dourthe et al., 2000.

Bus Concessions: Some Comments

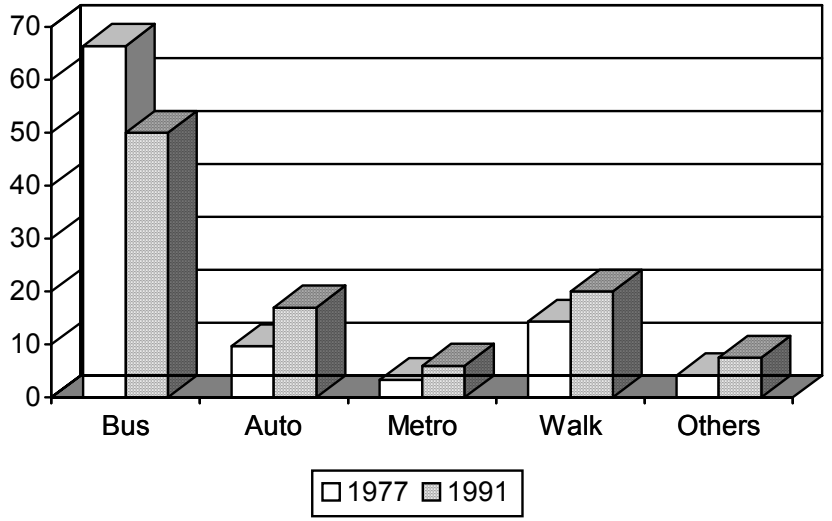
- Fare Reductions: Actually began before concession contracts in place (10/92)
- Current & Future competition?
  - Higher technical requirements (vehicles) imply fewer potential operators
    - 1998, 97% (280 routes) bid maximum fare: CH$190
    - 76% bid for just one route (return of collusion?)
  - Competition or price setting by Ministry?
- Despite reduced bus fleet size, still apparent excess capacity
  - particularly during certain times of day, on certain routes
- Safety, Security
  - Battle to implement new charging techniques (still unresolved)
  - Unable to change driver remuneration method
  - Still competition on the street

Passenger Travel Demand

1991 (last O-D survey)

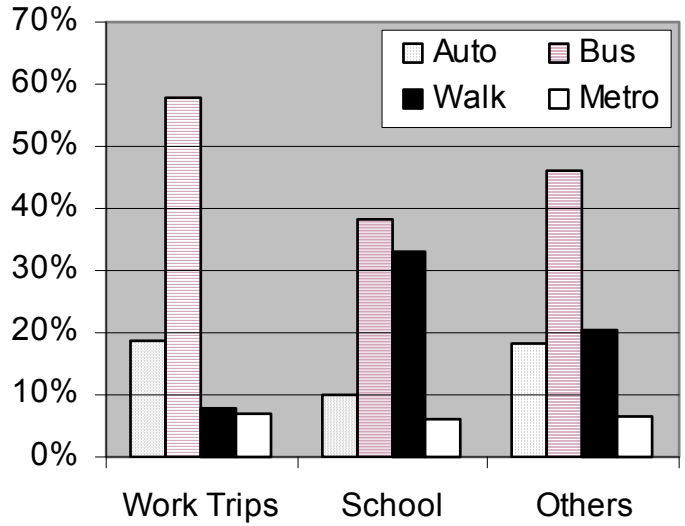
- 8.4 million trips/day
- 2.12 trips/person
  - 1.91 in poorest HHs
  - 2.65 in wealthiest HHs

Mode Share: % of All Trips



Source: Sectra, 1991.

Modes by Trip Purpose



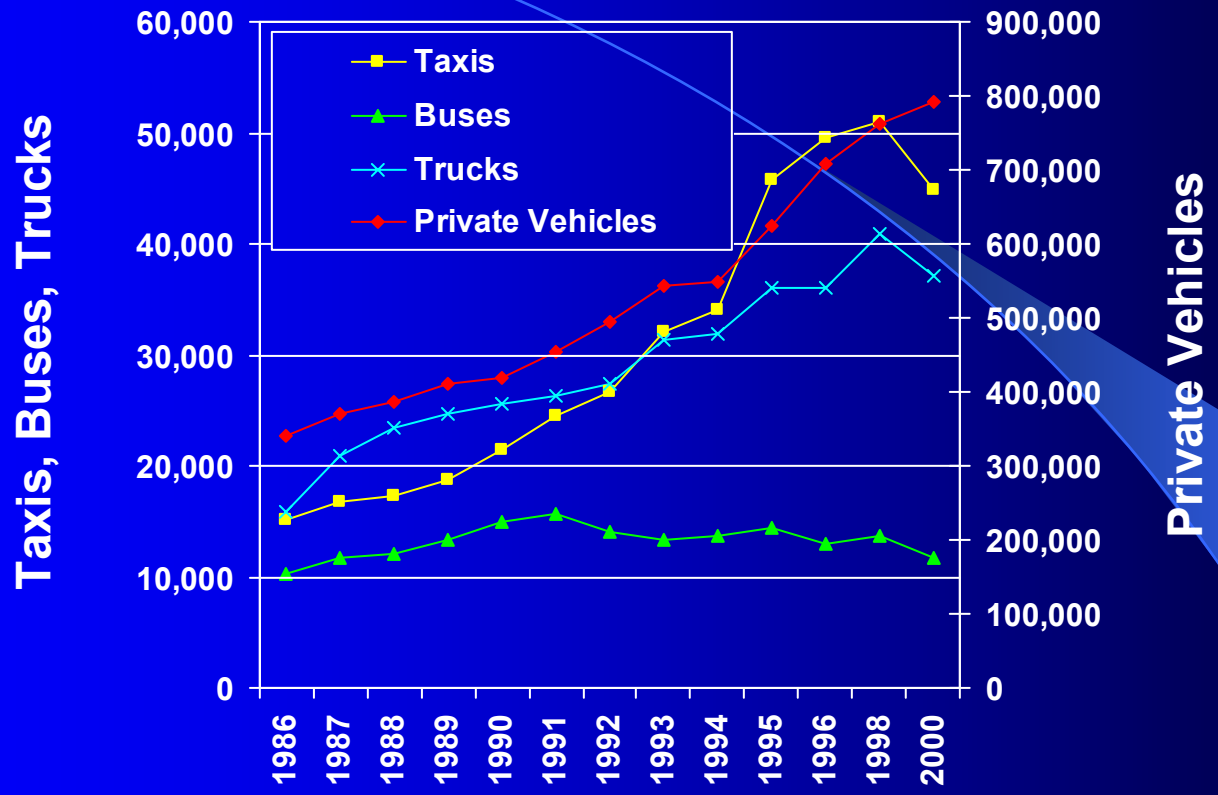
Note: Metro includes all combinations

Source: Sectra, 1991.

Trips by Purpose

- Work: 36%
- School: 32%
- Other: 32%
- Work and school predominate during peak periods; others constant across day

Vehicle Fleet



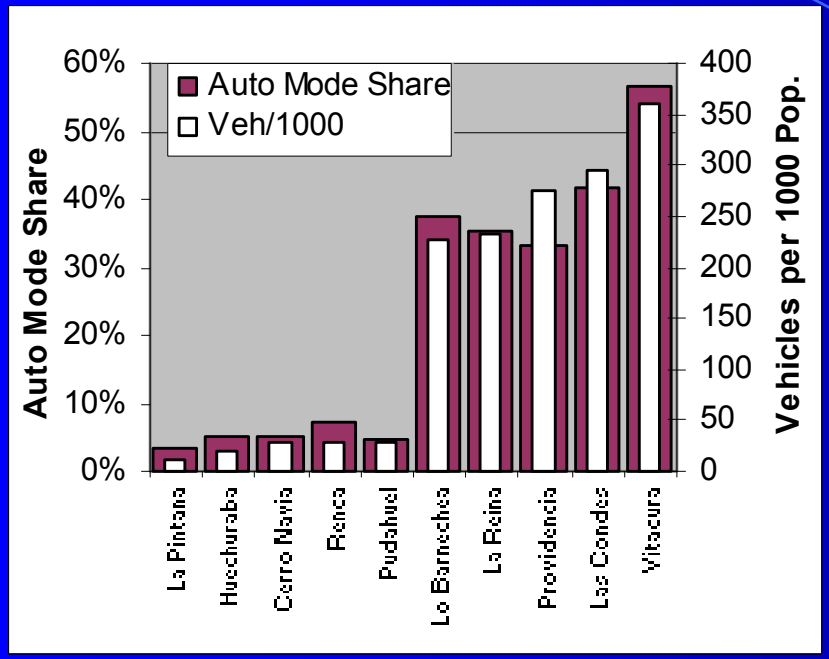
Fleet Growth Rates: 1986-1996

- Private Vehicles: 6%
- Taxis: 7.8%
- Buses: 1%
- Trucks 6%

Motorization Rate

- 1952: 14 private vehicles per 1000
- 1977: 60 private vehicles per 1000
- 2000: 129 private vehicles per 1000
- A.A. Growth 86-96: 4%

Wealth, Motorization, Mode Share



Motorization Rate & Income

- Kain & Liu (1994)
  - Income explains >90% of HH vehicle ownership
  - Income Elasticity: 1.06-1.16
- Zegras & Gakenheimer (2000) - using 1998 data for entire RM
  - % HH private vehicle ownership increases with Avg. HH income at elasticity of 0.82 (r^2=70)

Motorization Rate & Mode Share

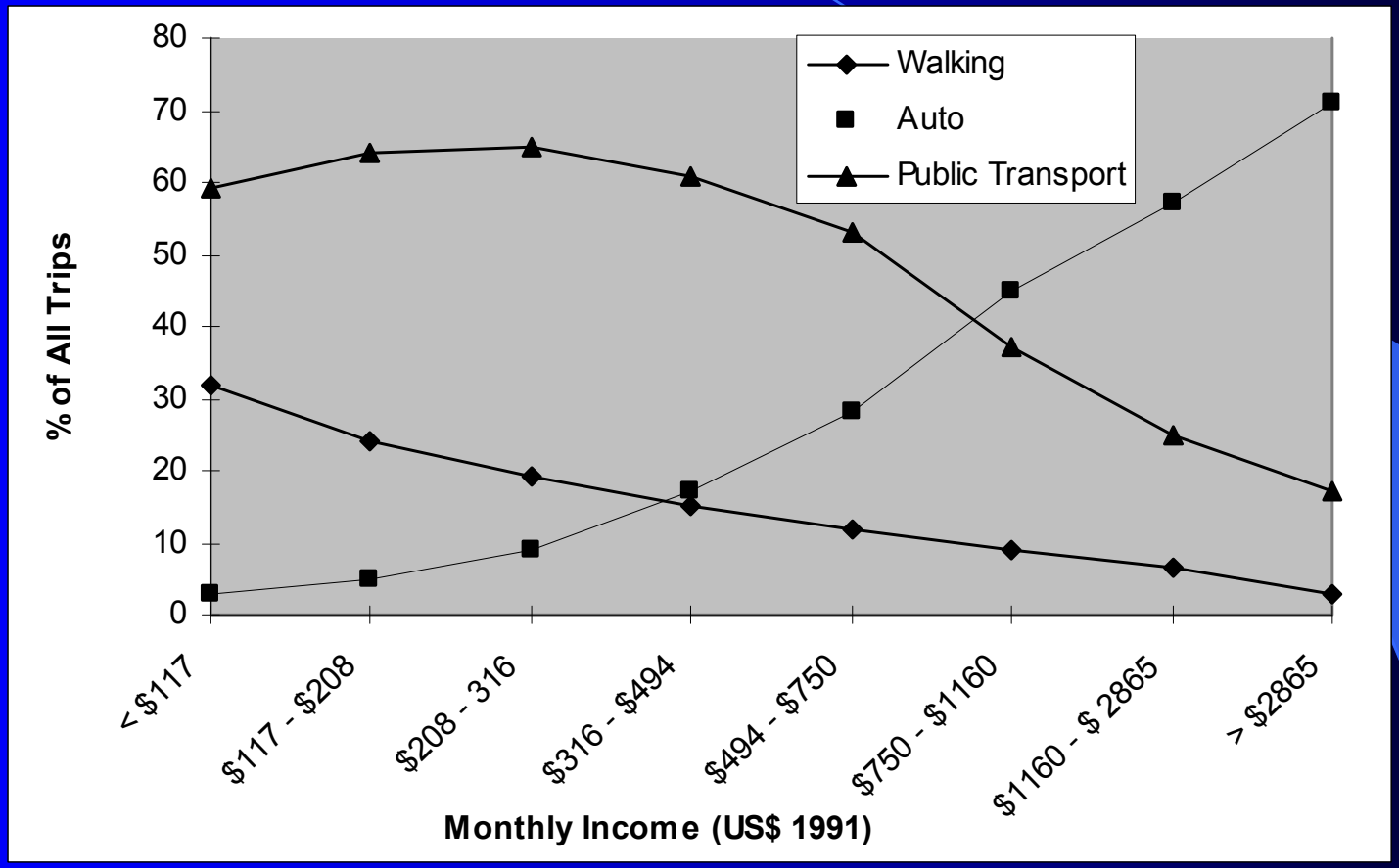
- Kain & Liu (1994)
  - Auto ownership explains 96% of auto use
  - Elasticity of auto mode share to ownership of nearly 1.
- Zegras & Gakenheimer (2000) estimates suggest a short term elasticity of 0.80 and long term of 1.22
  - Suggesting that today's auto mode share roughly 22%-24% of all trips

Motorization Rate, Mode Share, Trips – Growth in Time

	1977	1991	Annual Growth
Autos/ 1000 Population	60	90	3%
Auto Mode share	9.8%	15.8%	3.4%
Trips/Capita	1.14	2.13	4.4%
Motorized Trips/Capita	0.95	1.7	4.2%

Source: SECTRA, 1991.

Income, Motorization, Mode Share – What Future the Bus?



Source: Farah, et al, 1993.

Bus System – Ongoing Challenges

Specific to Private Sector Ownership-Operations

- On-Street competition for passengers
- Service and fare integration
  - Nearly all services run periphery to periphery
    - Often long, torturous routes, with duplication on dense corridors
- "Formalization" of the companies
  - Many traits of informal roots remain

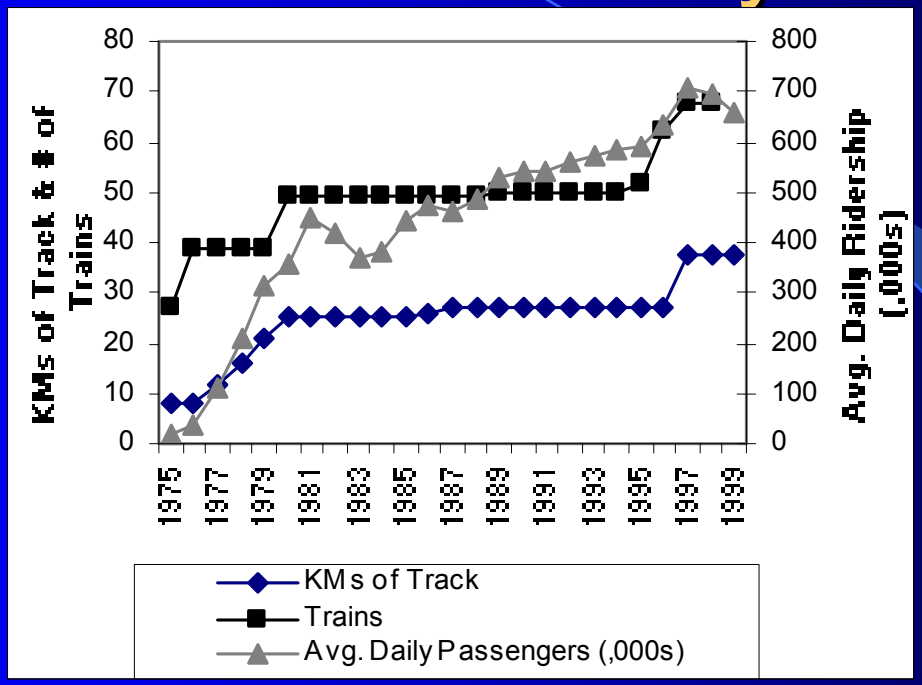
Challenges to the System in General

- Service & fare differentiation
  - Marginal cost pricing possible?
  - Higher quality service for higher paying patrons?
- Travel & wait time
  - Bus trip times on average 70% longer than auto
- Overall public perception & status – what role public policy?

For how much longer will the private operators be viable?

Bus System, Suburbanization, Equity

The Metro: A Public Transport "Success Story"?



- Generally increasing ridership with supply expansion
- Does it offer "alternative to the car"?
  - Metro's data shows that within "areas of influence" public transport mode share goes up to 76% (Metro 52%, bus 24%) (Metro, 2000)
  - At aggregate comuna level – controlling for auto ownership – public transport mode share positively correlates with Metro presence
    - $R^2 = 60\%$ (Zegras & Gakenheimer, 2000)

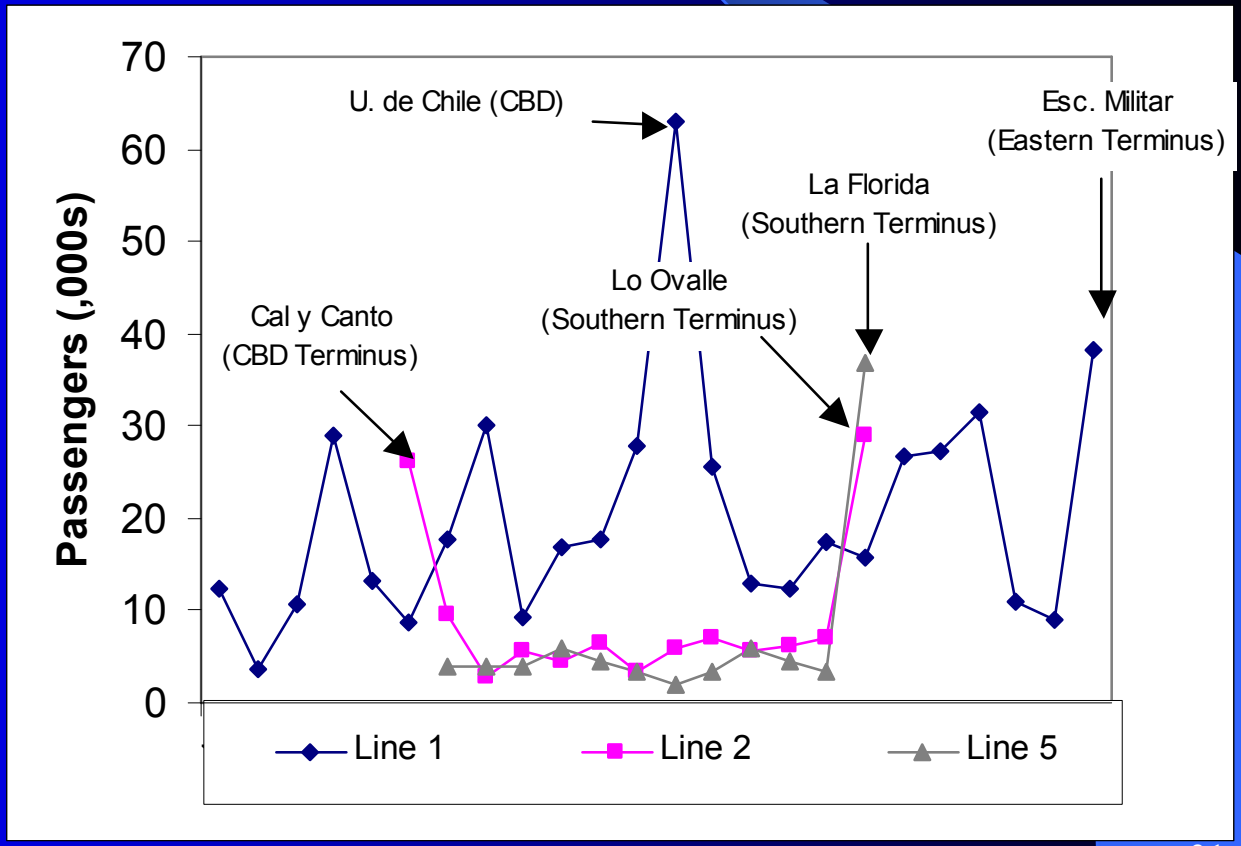
Metro: Performance Indicators

- Since 1995, has recorded operating surpluses
  - Incomes: fare, publicity, rent (locales in stations)
  - Costs: personnel, energy, maintenance, depreciation
- Uneven Line Utilization
  - Peak demands on Line 1 approach 70% of system theoretical capacity (50,000 pax/hour/direction)
  - Lines 2 and 5 less than 30%
  - Remember Mexico City?
    - Similarly, 35% of system (Line 1) carries 70% of users

Line 1 "Success" – Land Use

- Seven stations with >25,000 entering pass./day
  - Line 2 reaches this level only at terminal stations
  - Line 5 only at southern terminal station

- Line's 2 and 5 – cost savings measures (initial construction costs) reduce integration with urban fabric
- Great majority of Metro trips start and end as pedestrian trips (generally >65%)



Metro: Service Integration

- Despite minimal service integration, buses and *colectivos* provide important peak feeder service
  - 8-9 AM: 26% and 13%, respectively
  - 6:30 – 10 PM: 23% and 16%, respectively
- Integration terminals figure prominently in future expansion plans (so-called mini-extensions)
  - Hope, in part, to attract private capital
    - As in case of Line 5 Terminal – Bellavista de la Florida

Bellavista de La Florida

Metro expropriated land for a Metrobus transfer station and then, via a concession, granted development rights to a supermarket chain.

- Company invested ~ US$3.7 million to develop the underground transfer station in return for the rights to use the surface above for 40
-

Other Travel Modes

- ~3% (& growing) of trips are school bus trips
- *Colectivos* have increased from <2% in 1991 to 6% today
  - Distance-based fare, important services to lower density suburbs
- Walking accounts for 20% of trips
  - 33% of school trips; 20% of "other" trips
  - Average time: 16-19 minutes
    - Average distance ~1.5 kms
    - Implies lower total accessibility for the poor
- Despite favorable topography, climate bike use low (1.6% all trips)
  - A recent study (Ortuzar et al 1999) suggests a bike network of 3.2 km bikeways/km^2 would increase bike share to 6%
    - Primarily replacing bus trips

Transport, Land Use, Urban Form - Roads

- Anecdotally, road investments have played/ important role in development
  - in east, southeast suburbs
  - Industries on west, northwest Ring Road
- Highways "cause" expansion?
  - Lo Barnechea (in East) began developing before major road infrastructure expansion
    - Developers lobbied for expansion, development subsequently accelerated
  - La Florida suburbanized before radial road upgrades
  - Chacabuco (Province directly to North) development currently constrained by lack of road infrastructure

Transport, Land Use, Urban Form - Metro

- Eastern portion of Line 1 coincided with urban transformation and densification (Providencia, Las Condes corridor)
  - But, no comparable results on poorer, western segment in east, southeast suburbs
- Line 2 criticized for not generating land effects
- Line 5 – too soon to judge?
  - Bellavista de La Florida mall already existed
- Kain & Liu (1994): Metro encourages suburbanization
  - But, only if Metro investments did not substitute for other urban transport investments
    - Seems that, actually, Metro did take away from other investments
  - Did Line 1 "plant the seeds of its own destruction" by reducing importance of CBD?
    - Ridership profile suggests opposite effects

Transport, Land Use, Urban Form

- What role externalities?
  - Air pollution, noise, accidents
- Major traffic corridors, particularly running through the intermediate *comunas*
  - Does the increased accessibility implied by this traffic more than offset than negative effects?
  - Or, is it further fueling urban outgrowth?

Land Use, Urban Form, Transportation

- Predominant urban form of Greater Santiago (remember last week's slides on land uses)
  - historical concentration of trip attractions in city center;
  - socio-economic segregation, which produces long work, school, and shopping trips from lower income neighborhoods to upper income neighborhoods
    - Better concentration of employment, shopping, education opportunities
  - functional segregation, which results in many, often long, trips
    - from less-equipped zones to those with greater diversity of land uses
- Jobs/Housing Balance (1991) (Kain & Liu, 1994)
  - 13 comunas 0.8-1.8; 19 comunas 0.2-0.7
- School/Housing Balance
  - Relative imbalance: school trips have been important transport policy focus
    - Linked to prestige, long-run social contact "externalities"

Land Use, Urban Form, Transportation

Recent Trends (as seen last week)

- The migration of the CBD
  - Providencia, Las Condes, Vitacura (East)
  - Huechuraba, Quilicura (North) and Pudahuel (West, near airport)
- The emergence of the "edge city"
  - Potential to reduce suburb-center city travel
  - Potential to increase suburb-suburb travel

Land Use, Urban Form, Transportation

- The Local factors (3 D's)
  - Kain & Liu (1994) find little evidence of effects
    - Aggregate *comuna*-level data of density and mode share
  - Similar analysis at aggregate *comuna* level (Zegras & Gakenheimer, 2000)
    - Negative correlation between relative mix of land uses and walking
      - Implies that the poorer *comunas* (walking-dependent) have lower levels of overall accessibility
- More detailed, micro-level data required for more conclusive analysis
  - Rich area for future research….

T, L-U & Environment

Air Pollution

- RM in violation of standards
  - TSP, PM_{10}, Ozone, CO
- Risk of violation for NO_2
- Transport is principal source of PM_{10}, CO and – virtually – Ozone
  - Especially since ozone is apparently NOx-constrained

Transport and Air Pollution in RM

Vehicle Type	PM_{10}	CO	NOx	VOCs	SO_2
Cars and Light Trucks	1.5	72	34	34	3
Taxis	.1	11	4	5	.5
Trucks	2	8	20	4	6
Buses	3	2	13	2	5
Motorcycles	0	.3	0	.4	0
All Vehicle Types	86*	92	71	46	15

* Includes Road Dust.

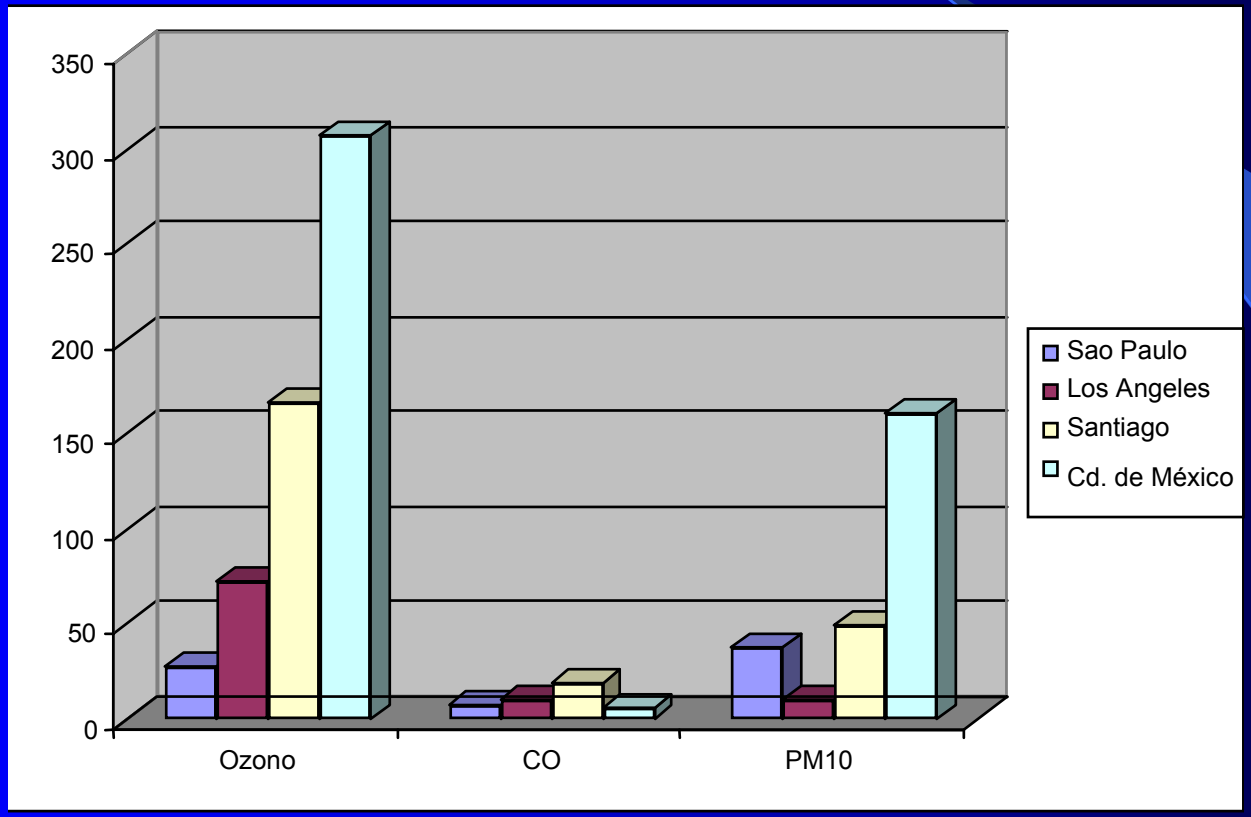
Source: CONAMA, 1998

AQ Management – History

- 1978 – first AQ norms
- 1988 – first monitoring stations
- 1990 – Special Commission for AQ established
- 1992 – first catalyst vehicles introduced
- 1994 – CONAMA created
  - national environment legislation passed
- 1996 – RM pollution violations "declared"
- 1997 – AQ management plan published
- 1997 – expansion of monitoring stations
- 1997 – development of first AQ prediction model
- 1998 – massive industrial conversion from diesel to natural gas
- 1998 – "emergency" levels revised, MC standards set
- 1998 – use of AQ model for formally anticipating episodes
- 2001 – introduction of "city diesel" (0.03% sulfur)

RM Air Pollution in an International Context

Number of Times Norm Exceeded in One Year

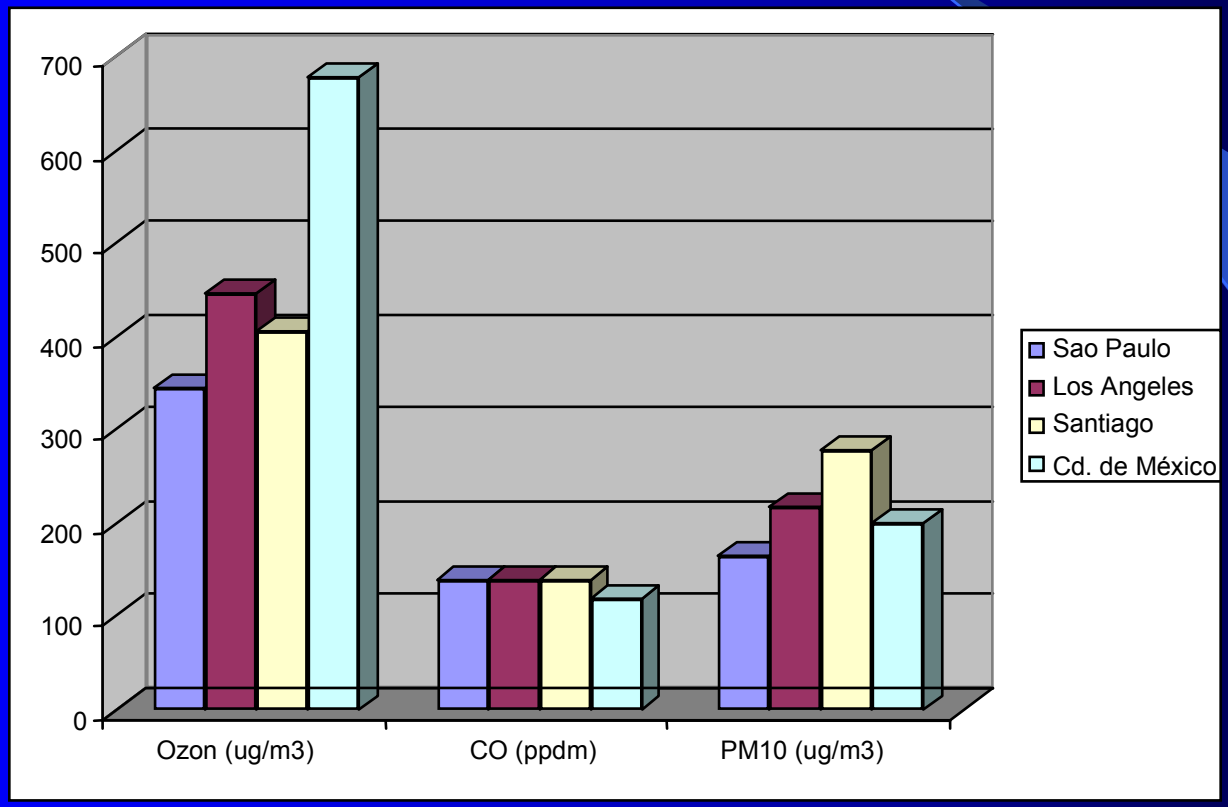


Note: Various years b/w 1995-98

Source: Lents, et al, 1999.

RM Air Pollution in an International Context

Maximum Pollution Levels Reached



Note: Various years b/w 1995-98
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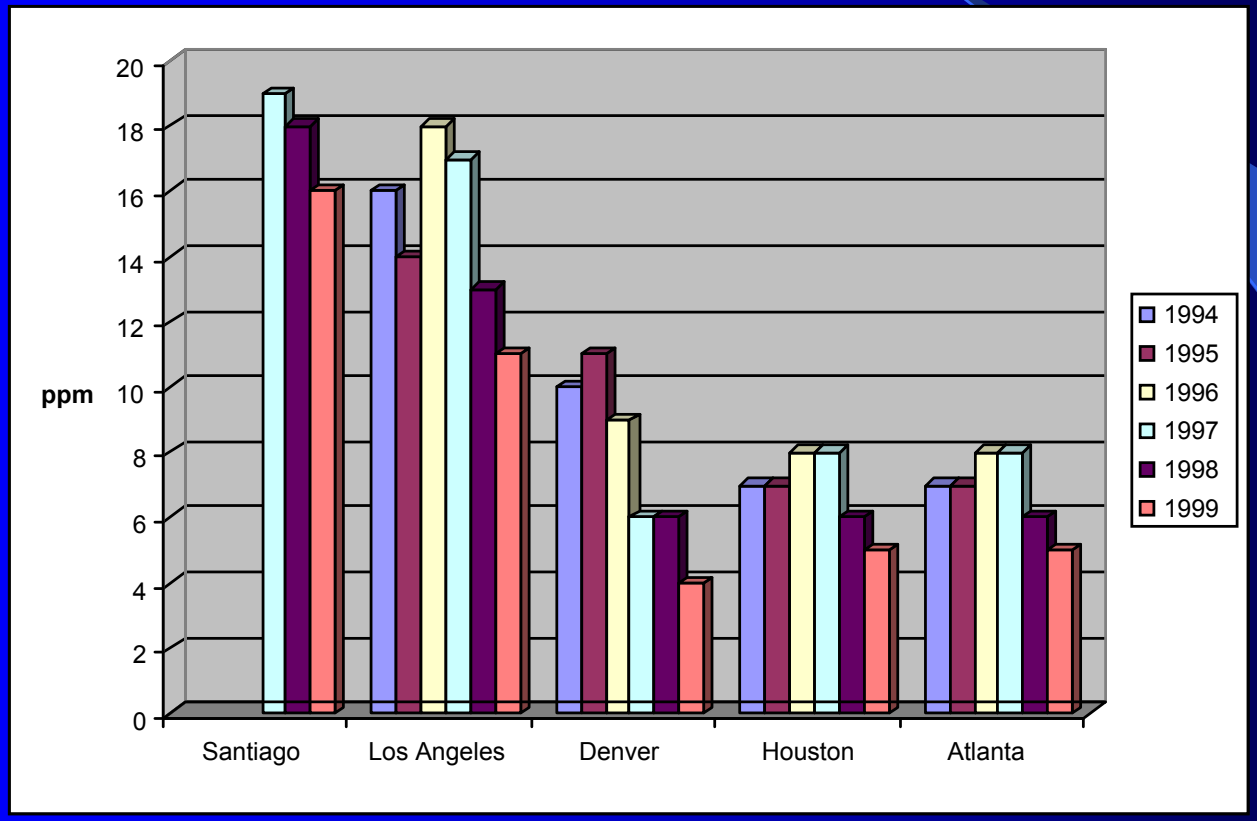
RM Air Pollution in an International Context

US Cities & Santiago: Maximum CO Levels Reached



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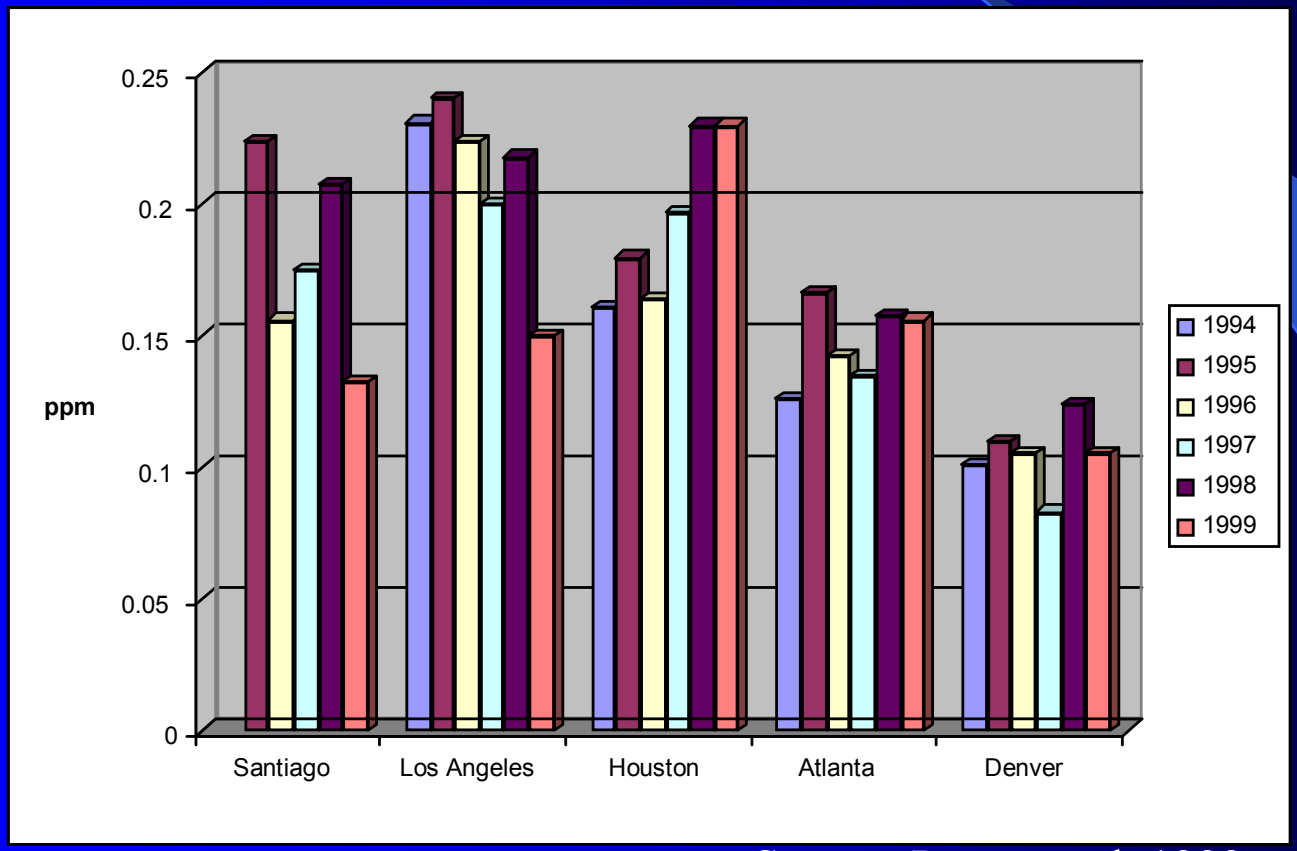
RM Air Pollution in an International Context

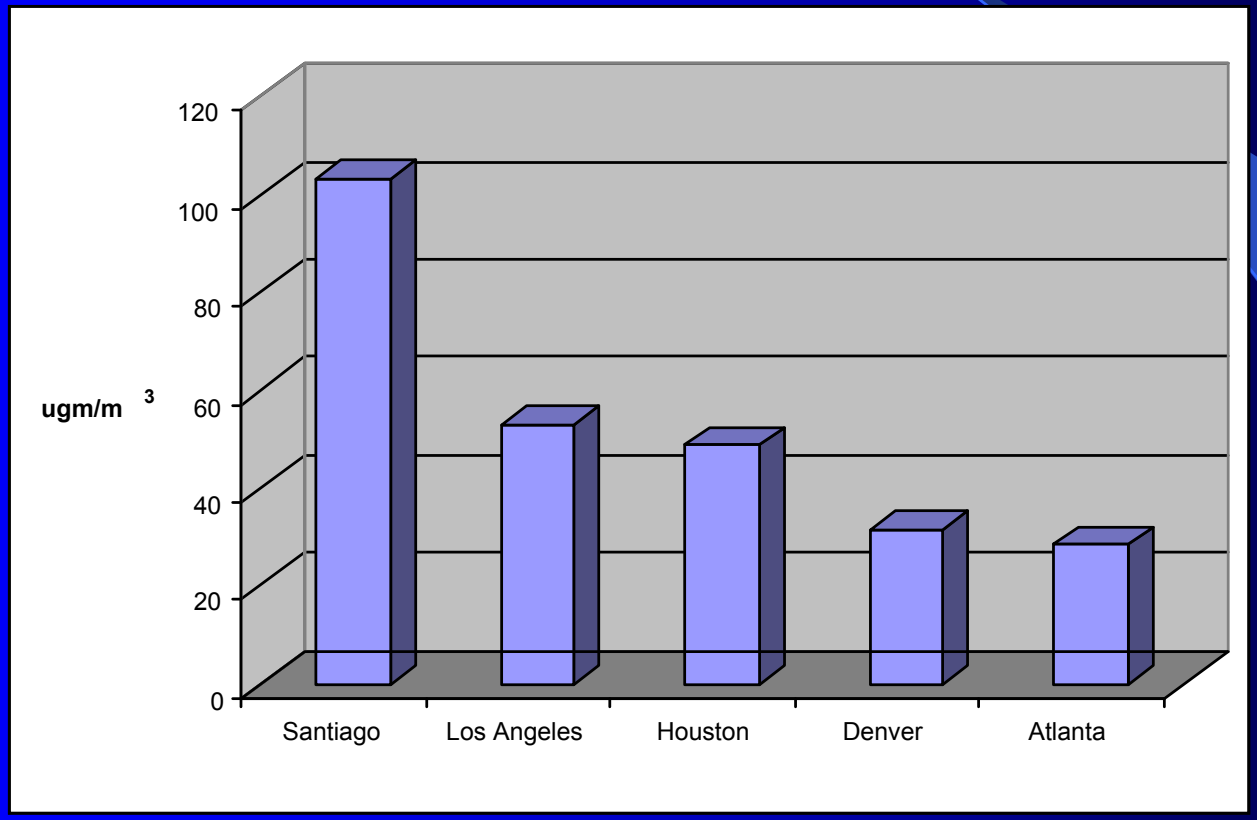
US Cities & Santiago: Maximum Ozone Levels Reached



Source: Lents, et al, 1999.

RM Air Pollution in an International Context

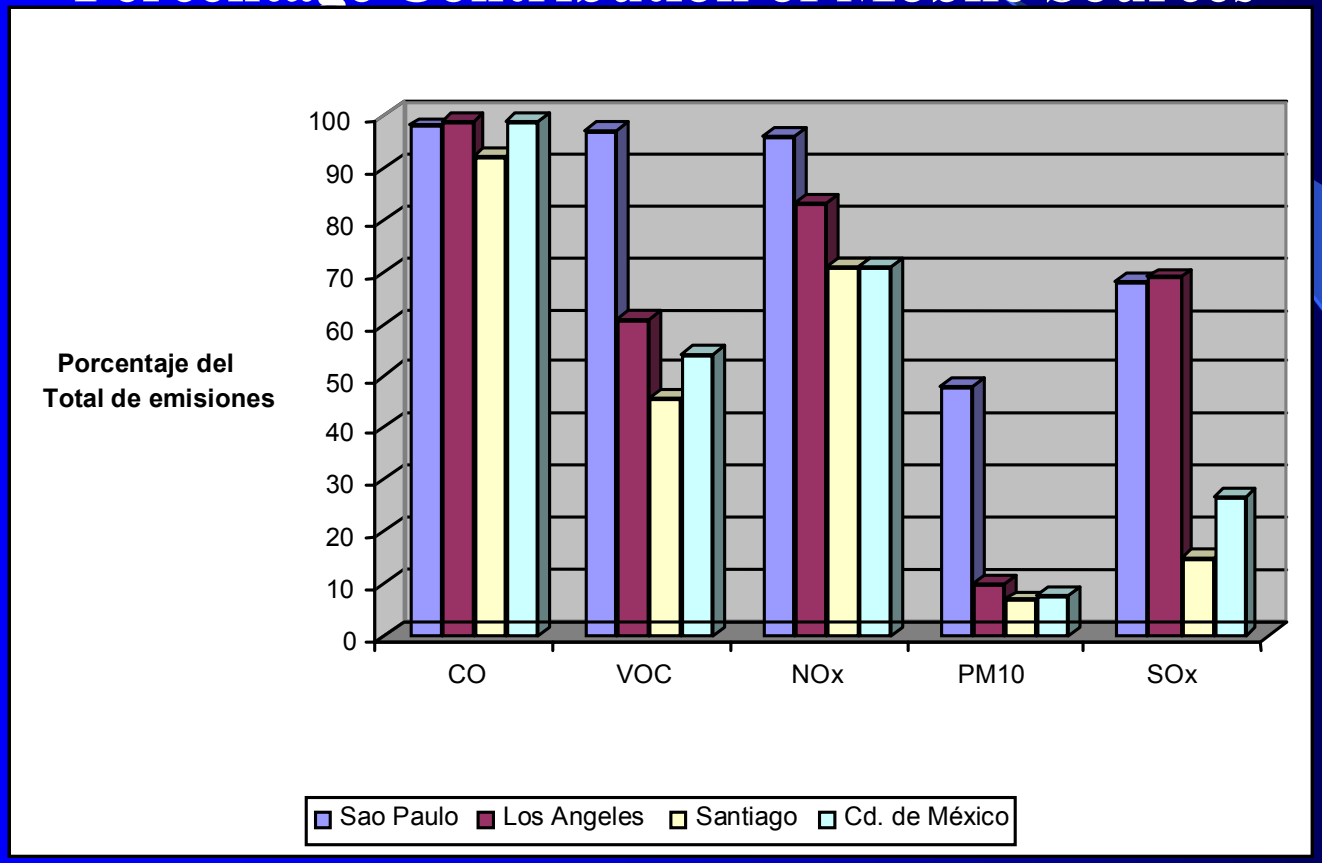
US Cities & Santiago: Average PM_{10} Levels: 1997-99



Source: Lents, et al, 1999.

RM Air Pollution in an International Context

Percentage Contribution of Mobile Sources



Source: Lents, et al, 1999.

Air Pollution Progress

First Half of 1990s (1989-95)

- PM_{10}
  - "emergency days" declined from 10 to 0
  - "pre-emergency" from 30 to 10
- CO
  - Days in violation declined by ½ to 56 in 1995
- Ozone – more persistent, considerably varied across region

1997-2000

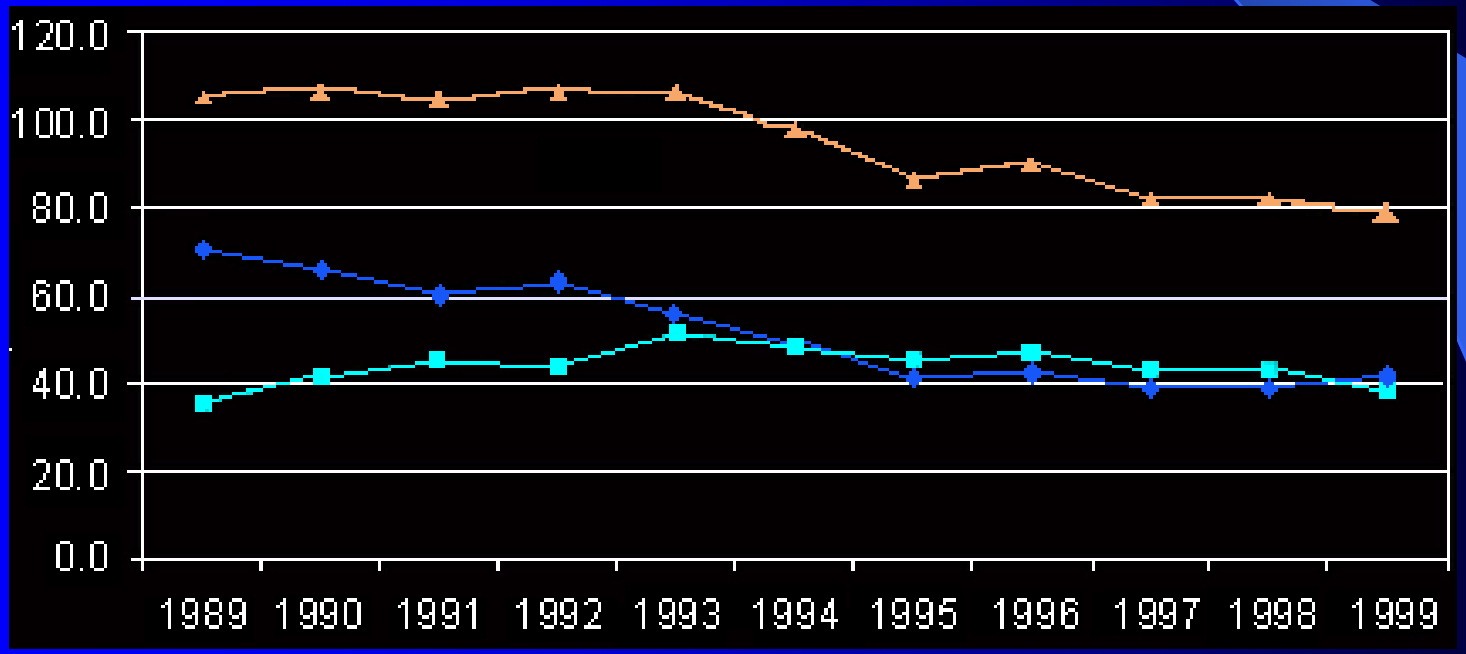
- 1% reduction in ozone (still 45% from standard)
- 31% reduction in CO (still 35% from standard)
- 23% reduction in avg. PM_{10} (still 35% from standard)

Episode Definition

Based on PM Concentration:
Index of Air Quality for Particulate Matter (ICAP)

ICAP	Category ICAP	PM10 ug/m3 (24 hrs.)	Level	Episode
0-100 Good	0	0	0	-
101-200 Regular	100	150	0	-
201-300 Bad	200	195	1	Alert
301-400 Critical	300	240	2	Pre-Emergency
401-500 Dangerous	400	285	2	Pre-Emergency
>501 Excede	400	330	3	Emergency

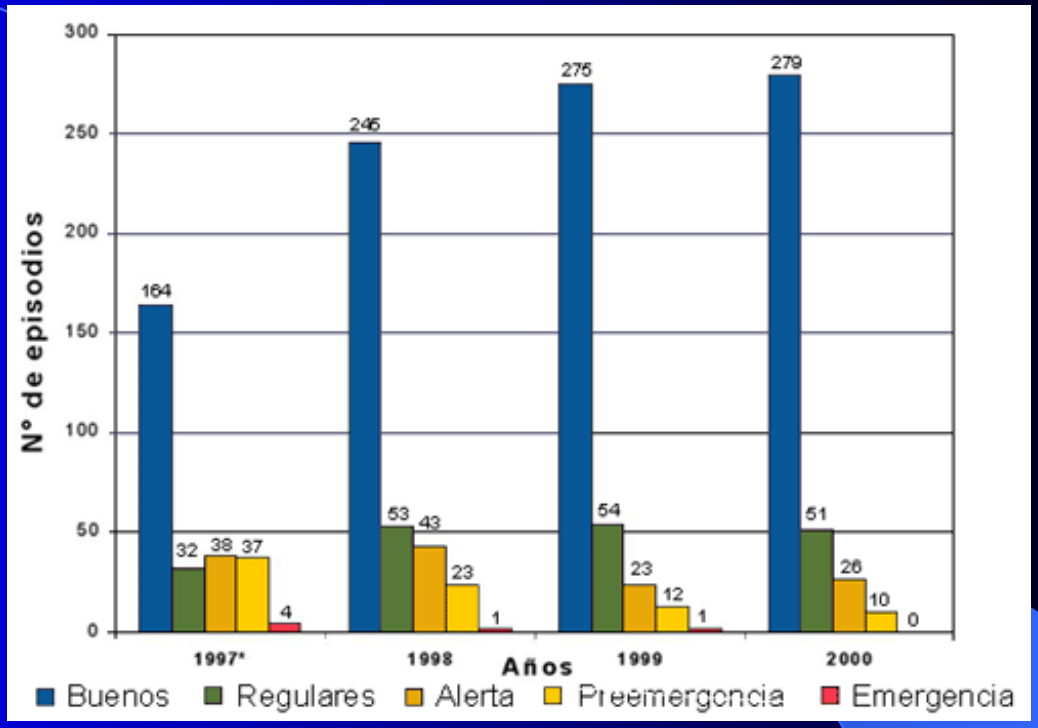
PM_{10} Concentrations – Average Annual



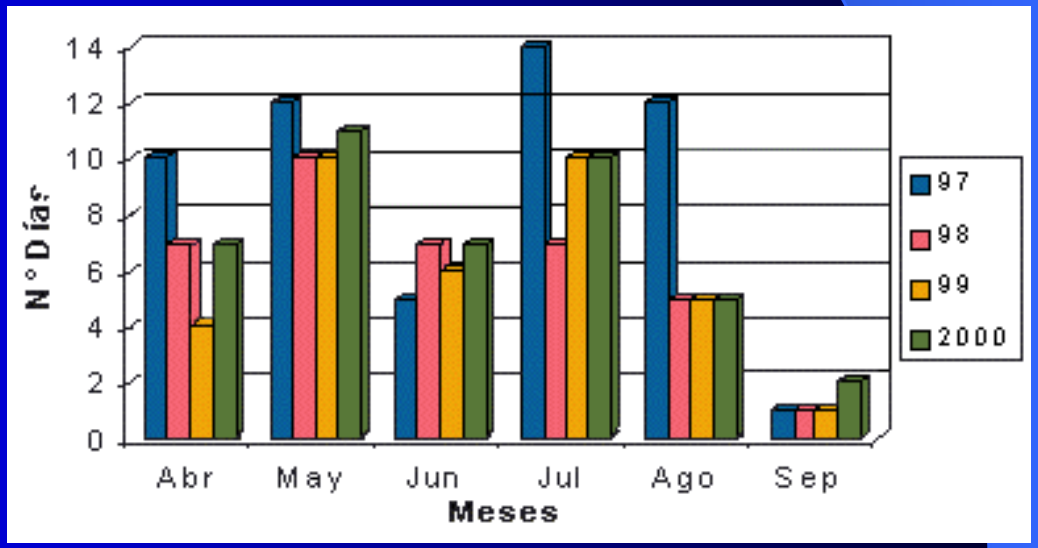
Source: www.conama.cl/rm

Recent History: Episodes

Annual Episodes



Monthly Distribution



Source: www.conama.cl/rm

T, L-U, Environment – Other Concerns

- Land conversion – loss of agricultural land, pressures on wetlands, loss of fragile foothills
  - Implications for erosion, flood control, species loss, micro-climate
- Water pollution, depletion – untreated residential and industrial sewage, nitrate deposition, groundwater depletion (esp. Chacabuco)
- Noise pollution – 80% of population living or working on principal arterials at risk of hearing loss (as of 1989)
  - 70% of residential, mixed use land inadequate for these uses due to noise
- Solid waste disposal – 80% of domestic waste makes it to landfills, but most industrial waste disposed illegally, waste growing 2% year
- Open spaces – less than 2.5% of urbanized area dedicated to open space (40% less than international norms)

The Public Intervention Space

- Finance
  - Taxes, transfers, subsidies, impact fees
- Planning Interventions
  - Urban and Regional Plans, Sectoral Plans
- Impact Studies
  - Transport System Impact Studies, Environmental Impact Studies, Urban Impact Studies.

Public Finance

Central Government

- Still most important government level
  - 95% of all taxes collected
  - Major investor, redistributive role, rule-setting role for Municipal government revenue-raising
- Revenues: 60% from VAT and other consumption taxes; 30% through income taxes; 12% through customs duties
- Essentially neutral spatial effects
- Apparent RM subsidy to other regions (via transfers to Regional, Municipal governments

Public Finance

Regional Government

- No revenue-raising capacity
- Fully dependent on transfers from Central Government
  - FNDR (*Fondo de Desarrollo Regional*)
    - Redistributional
  - ISAR (*Inversion Sectorial de Asignacion Regional*)
    - Assigned to Ministry and Region, GoRe determines where to spend from Ministry-approved projects in roads, housing
  - IRAL (*Inversion Sectorial de Asignacion Local*)
    - To be funneled through regional governments to Municipalities
- In RM, 1993-97: FNDR+ISAR+IRAL = $140 million
  - FNDR(44%), ISAR (44%), IRAL (14%)
  - Heavier relative focus outside of Greater Santiago
- Ongoing plans to decentralize investment decision-making
  - But, as of 1998 regional funds account for just 8% of total public investments in RM
  - Furthermore, who really controls the ISAR?

Public Finance

Municipal Government

- Property Tax
  - Absent transfers, single largest source of local revenues (76%)
  - Collected by Central Government
  - Despite law, very infrequent re-appraisals
  - Slightly progressive structure
- Vehicle Registration Fees (*permiso de circulacion*)
  - Buoyant
  - 1% to 4.5% of vehicle value
  - Even after transfers to FCM, important source of Municipal revenues – i.e., 20% in Providencia
- Business Licenses
  - Santiago, Providencia, Vitacura, Las Condes must contribute 55%-65% of fees to FCM
- FCM (*Fondo Comun Municipal*) – redistributive mechanism
  - 60% property taxes, 50% vehicle registrations, other fees
  - Even after redistribution, riches comunas 8x income/capita than poorest

Public Finance

Transport Finance

- Road user revenues (Gas tax, registration fees) apparently more than cover expenditures
  - Apparent subsidy to Metro
  - Does not take into account external costs
- Much rhetoric, little movement on road-pricing
  - Legislation stalled in Congress
- Infrastructure concessions
  - PanAmerican Highway, Costanera Norte, Radial Nor-Oriente
- Metro
  - Infrastructure financed by Central Government
  - Operations covered by revenues
  - Some minimum private sector participation (Bellavista de La Florida), possibly increasing in future

Plans

- PRDU (Regional Plan for Urban Development
  - A guiding instrument, created by Seremi-MINVU
  - Non-existent in practice
- Inter-Comunal (PRMS), 1960, 1994, Modifications
  - Created by Seremi-MINVU
  - General land use zoning, growth boundaries, densities, major infrastructure rights of way
  - 1994 Plan
    - Sets UGB, raises densities (city-wide to 150/hectare), specifies land use zones, establishes greenspaces, preservation zones, “sub” centers
    - Modified in 1997 to open up the Province of Chacabuco

Regional Plans - Comments

- Chacabuco Province
  - Plan adds 35% (19,000 has) to metro area's current urban area
  - Province actually contains 190,000 has…..
- Do financial pressures/interests over-ride all plans?
  - Expose inherent conflicts/contradictions
- What about coordination with other plans (i.e., various transport plans, environment plans)
- What about the PRI being developed for the South of the RM?

The Growth Boundary

- In 1994 PRMS, modified in 1997 with Chacabuco
  - Enforced through provision of public infrastructure
- Existence too short to gauge true impacts on land markets
- Probably slowed growth that otherwise might have occurred
  - "bought time" for creation of other instruments
  - Lessened impact of the Law of Agricultural Parcels
- Future role: depends on future modifications….