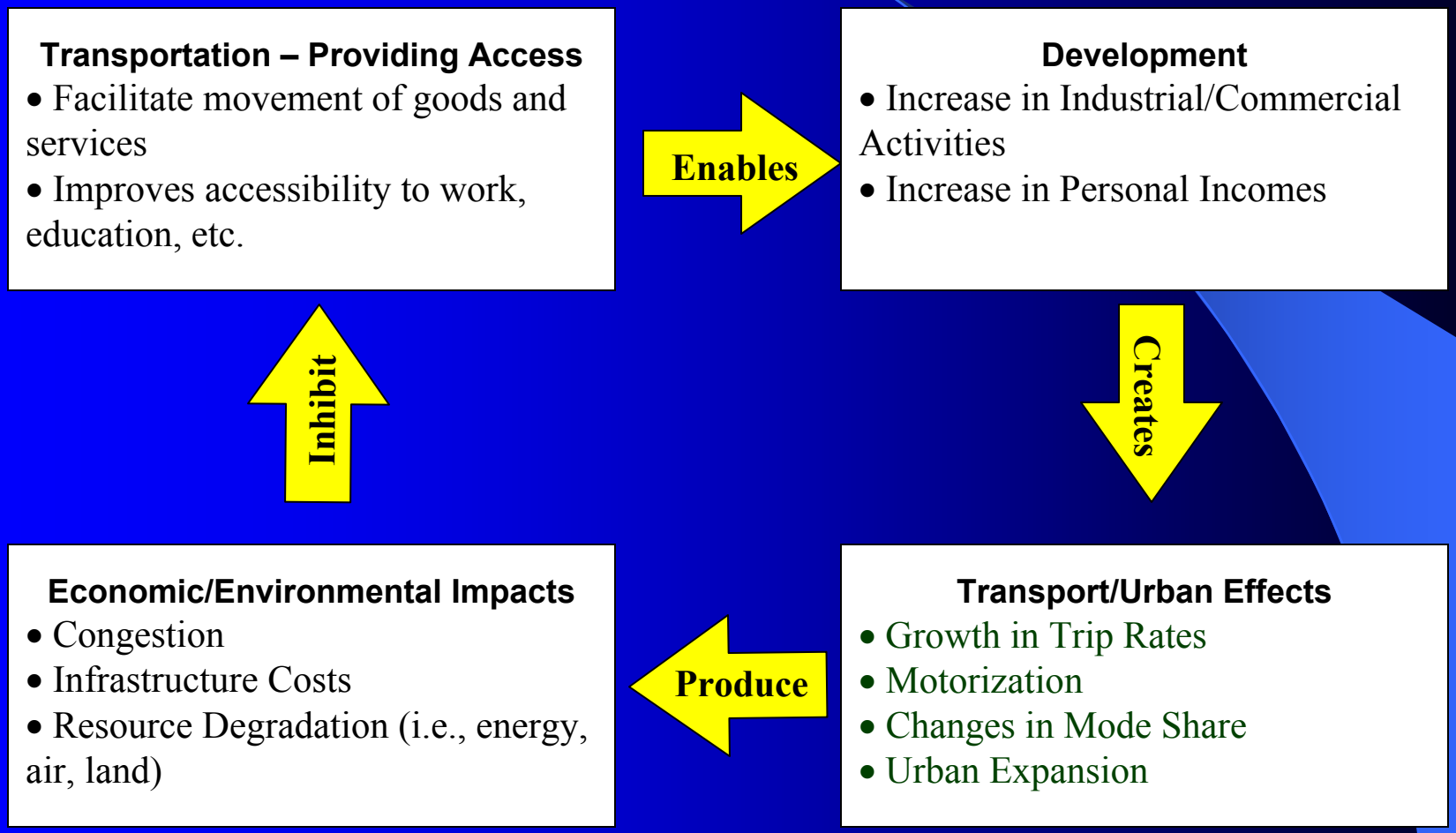
# Urban Transportation, Land Use, and the Environment in Latin America: A Case Study Approach

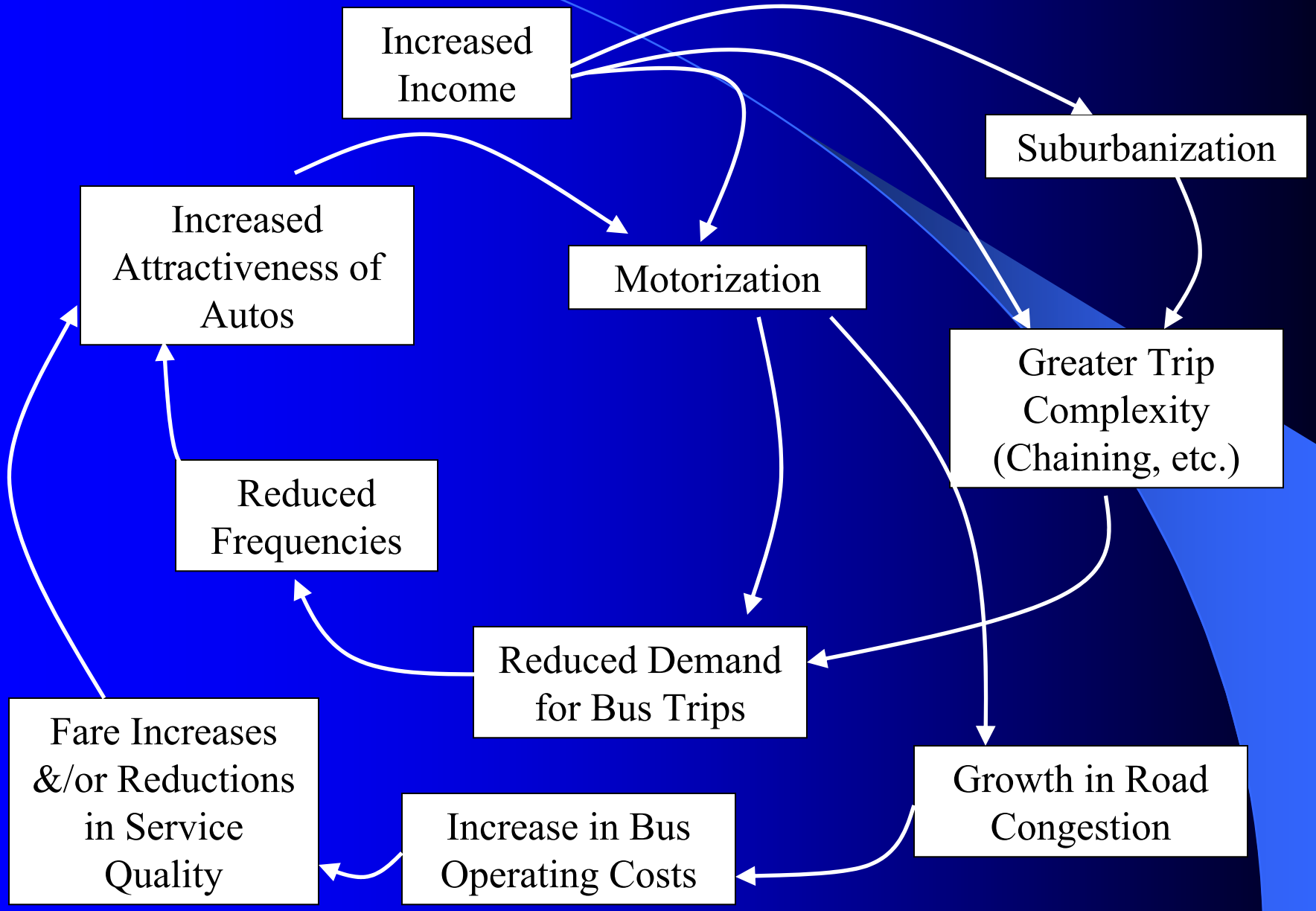
*Lecture 2*

1. *Urban Transport and City Development in Latin America (Cont'd from Lecture 1)*
2. *Urban Transportation and Sustainability – the Three E's*

# Urban Transport's "Vicious or Virtuous" Cycle



# Automobility & the Forces Against the Bus



# Bus vs. Auto – Travel Speeds

Average, Evening Peak Speeds (Km/hr) – Brazilian Cities

| City | Auto | Bus |
|---|---|---|
| Belo Horizonte | 23 | 16 |
| Brasilia | 45 | 27 |
| Campinas | 24 | 17 |
| Curitiba | 22 | 19 |
| João Pessoa | 26 | 18 |
| Juiz de Fora | 30 | 21 |
| Pôrto Alegre | 29 | 20 |
| Recife | 24 | 14 |
| Rio de Janeiro | 26 | 19 |
| São Paulo | 16 | 11 |

Source: Vasconcellos et al., 2000.

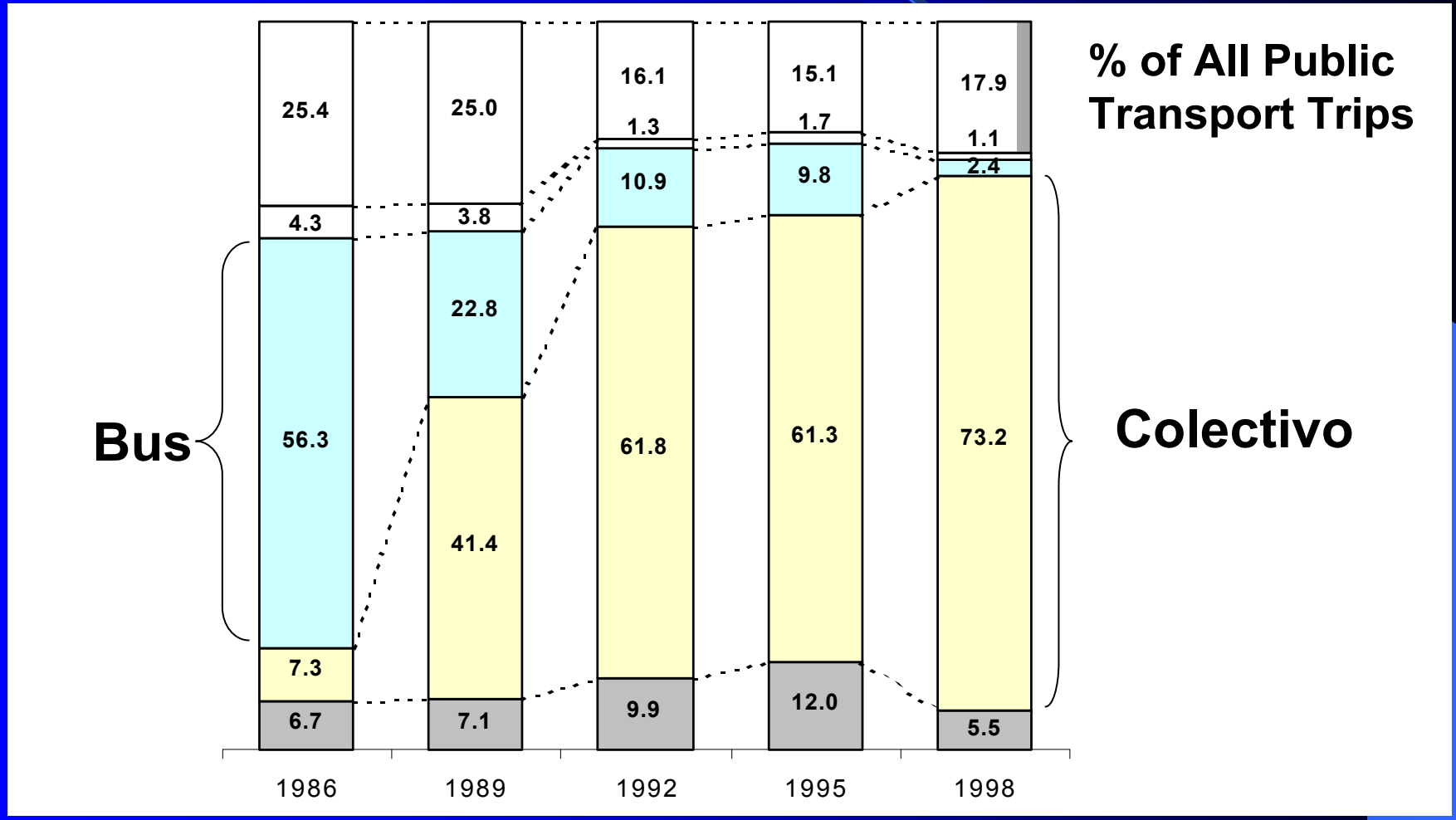
# Growth of the "Informal" Sector

- Minibuses, shared sedans, vans, etc. illegal or licensed but with little regulatory effort or power
  - Mexico City, Lima, Recife (Brazil), San Jose (Costa Rica), etc.
- Combination of initiating factors:
  - Liberalization of the public transport market, scarce alternative employment opportunities, public sector employment restructuring (Peru), institutional weakness
- Positive Impacts
  - Employment, fill demand with "door to door" service
- Negative Impacts
  - System-wide effects (congestion, pollution), political clout, unsafe on-road competition

# “Informal” Sector

- Rio
  - Kombis: complementary service in inaccessible areas
  - 14-seater “luxury” vehicles: competing express service
  - Fares 2 to 3 times equivalent bus fare
  - Early 1990s, 600 vehicles; today, 6,000 to 9,000
  - Buses have responded to competition, diversifying operations and adding amenities (i.e., A/C)

# The Rise of the "Informal" Sector in Mexico City



# Urban Rail Transit

- Metros, suburban rail, light rail
- Typically the exception in developing cities, including Latin America
  - High capital costs, lack of flexibility in adapting to changing travel patterns, long construction times
  - Still, often highly prized as visible, “modern” solutions to transport problems

# Suburban Rail in Latin America

- Suburban Rail in Buenos Aires, Santiago, São Paulo, Rio, and several other Brazilian cities
- Buenos Aires
  - 7 lines, 840 kms, 8% of trips
- Rio
  - 264 kms, 2% of trips
- São Paulo
  - 6 lines, 270 kms, 2% of trips
- Santiago
  - 1 line, 85 kms, <<0.3% of trips

# Metros in Latin America

| | Lines | Kms | Stations | % Trips |
|---|---|---|---|---|
| Buenos Aires | 5 | 44 | 67 | 5 |
| Caracas | 3 | 46 | 40 | na |
| Mexico City | 10 | 180 | 167 | ~13 |
| Rio (incl LR) | 2 | 35 | 30 | ~3 |
| São Paulo | 3 | 49 | 46 | 5 |
| Santiago | 3 | 40 | 51 | ~7 |

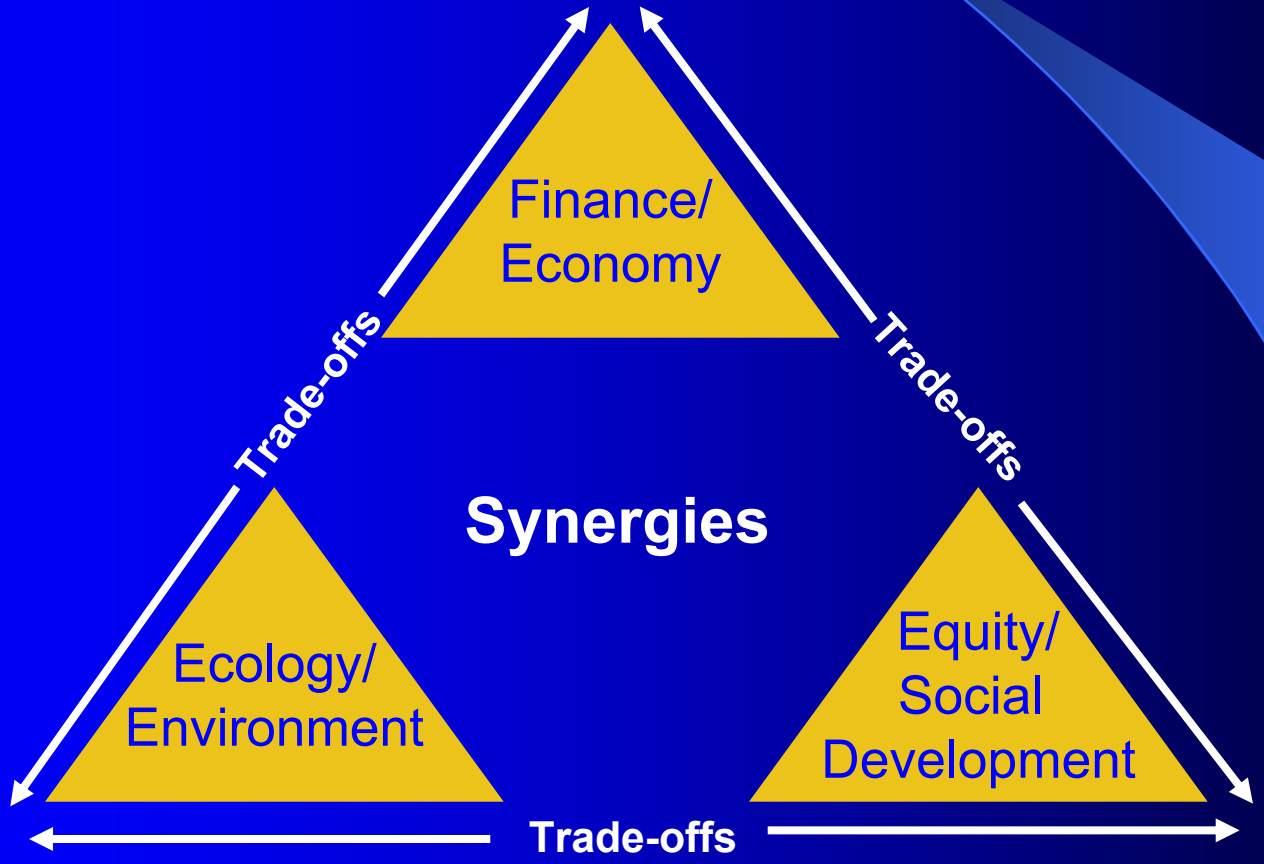
# Metros

- High Capacity – 60 Passengers/Hr/Direction
- High Cost - $40-$150 mn./Km
- Capital Costs rarely if ever recovered
- Operating Revenues/Operating costs – "Farebox Ratio" (in 1990)
  - Mexico City, Rio, São Paulo < 1
  - Santiago > 1.5
  - Policy outcome, planning outcome, operations outcome?

# Approaches to Sustainability

- The Three "E's" (or the Three Pillars, Three Dimensions, etc.):
  - Economics, Environment, Equity
    - Can Economic Growth (development) be achieved with Ecological Balance and Social Progress?
- WBCSD *Mobility 2001* adds to the Three E's
  - Operational Sustainability
    - Can our transportation systems continue operating
- Others have suggested additional elements
  - Particularly Institutions or Governance

# The Three E's: Compatible or Contradictory?




Source: World Bank, 1996.

# Sustainability & Transportation

- Can the transportation system itself be sustainable?
- Can a sustainable transportation system exist, but contribute to a larger, unsustainable global economic system?
- What do we mean by sustainable?

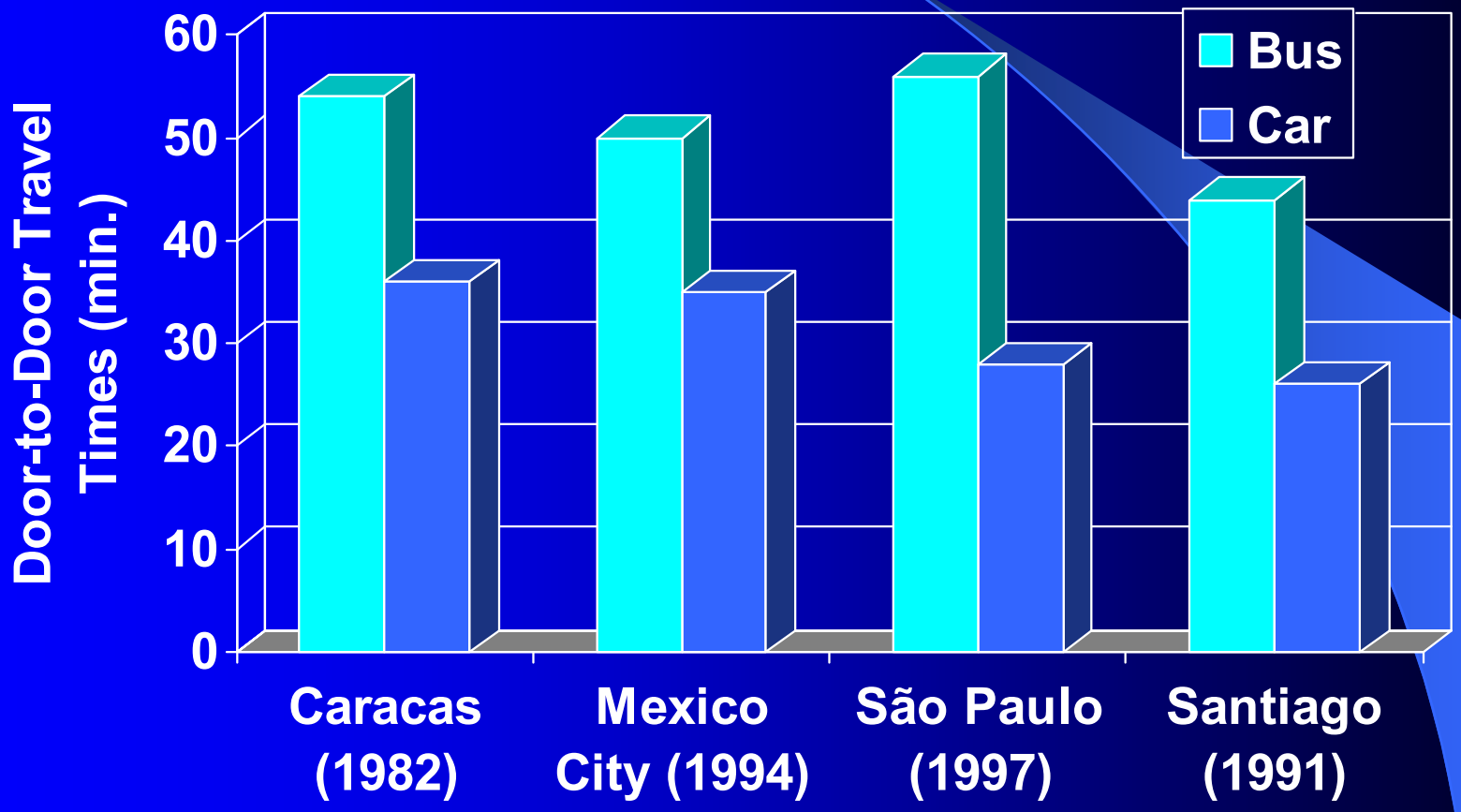
# The Three E's as Guiding Principles in Urban Development and Transport

- Economic/Financial Sustainability
  - Ensure that cities continue to support economic development
- Environmental/Ecological Sustainability
  - Generate an overall improvement in quality of life
- Social Sustainability (Equity)
  - The benefits should be shared equitably by society
- How Can These Principles Help Guide Policies, Strategies, Decisions?

# Social Sustainability

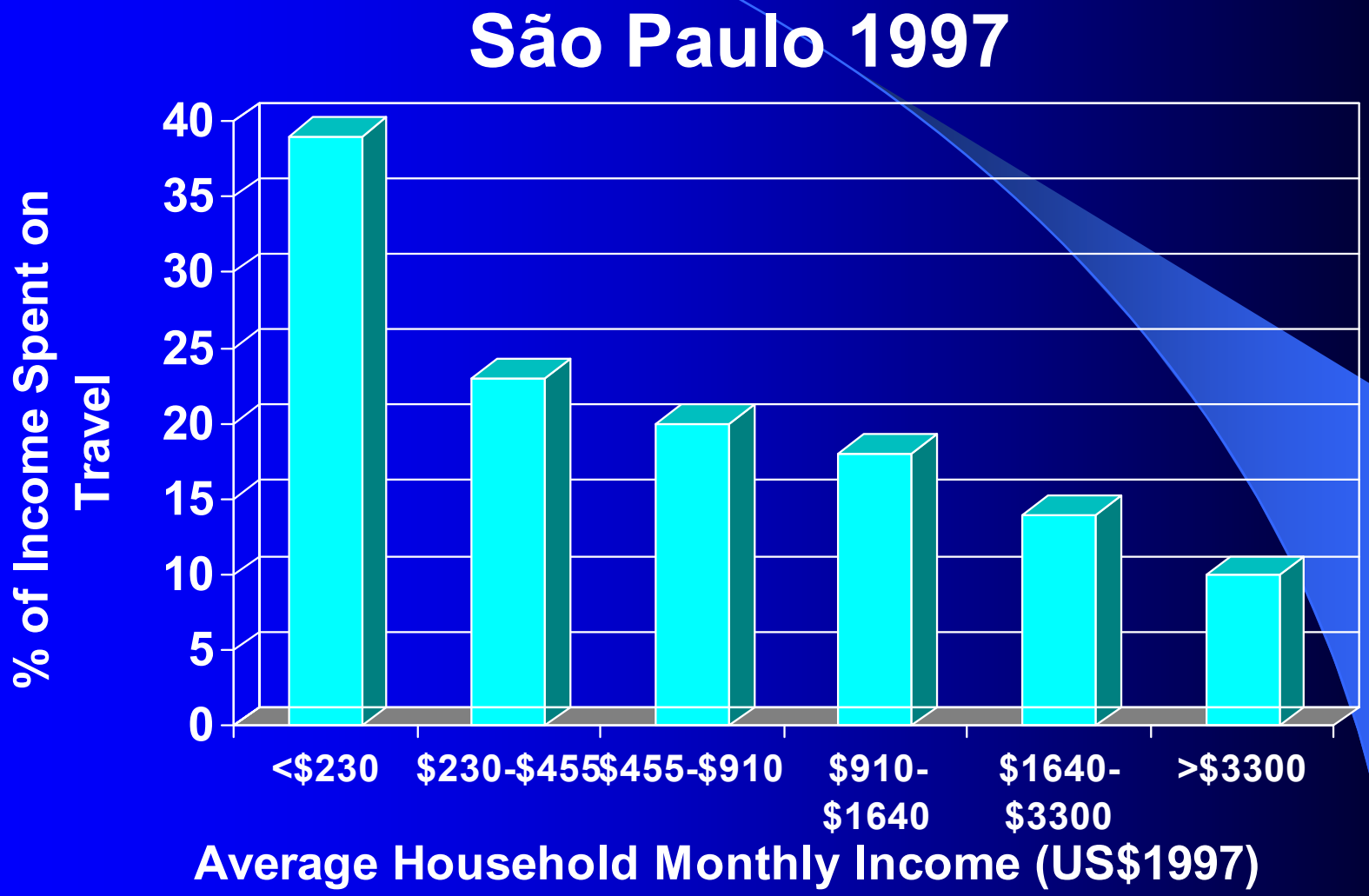
- Mobility (providing *accessibility* to jobs, education, recreation, etc.) serves as key "lubricant" to sustaining our basic social systems
- Mobility "opportunities" are unequally distributed across countries and within countries/cities
  - Trip possibilities, trip rates, trip times, travel conditions
  - Income, gender, age, race/ethnicity
- Mobility and its infrastructures produce disparate negative impacts across different groups
  - Accidents, noise, "barrier" effect, pollution, etc.

# Equity – Travel Times




Sources: SECTRA, 1991; Vasconcellos, 2001.

# Equity - Expenditures




Source: Vasconcellos, 2001.

# Accidents – Social & Economic Impacts

- Traffic Risk (fatalities per vehicle)
  - typically 2 to 10 times higher in developing countries
- Causes: Lack of institutional, engineering, infrastructure interventions
  - High degree of mixed/conflicting road users
  - Poor driver training, enforcement, low penalties, health care system
- Poorest typically suffer the greatest burden
  - Most vulnerable road users
- Social Impact – pain, suffering, loss
- Economic Impact – Lost productivity, material costs, resource allocation

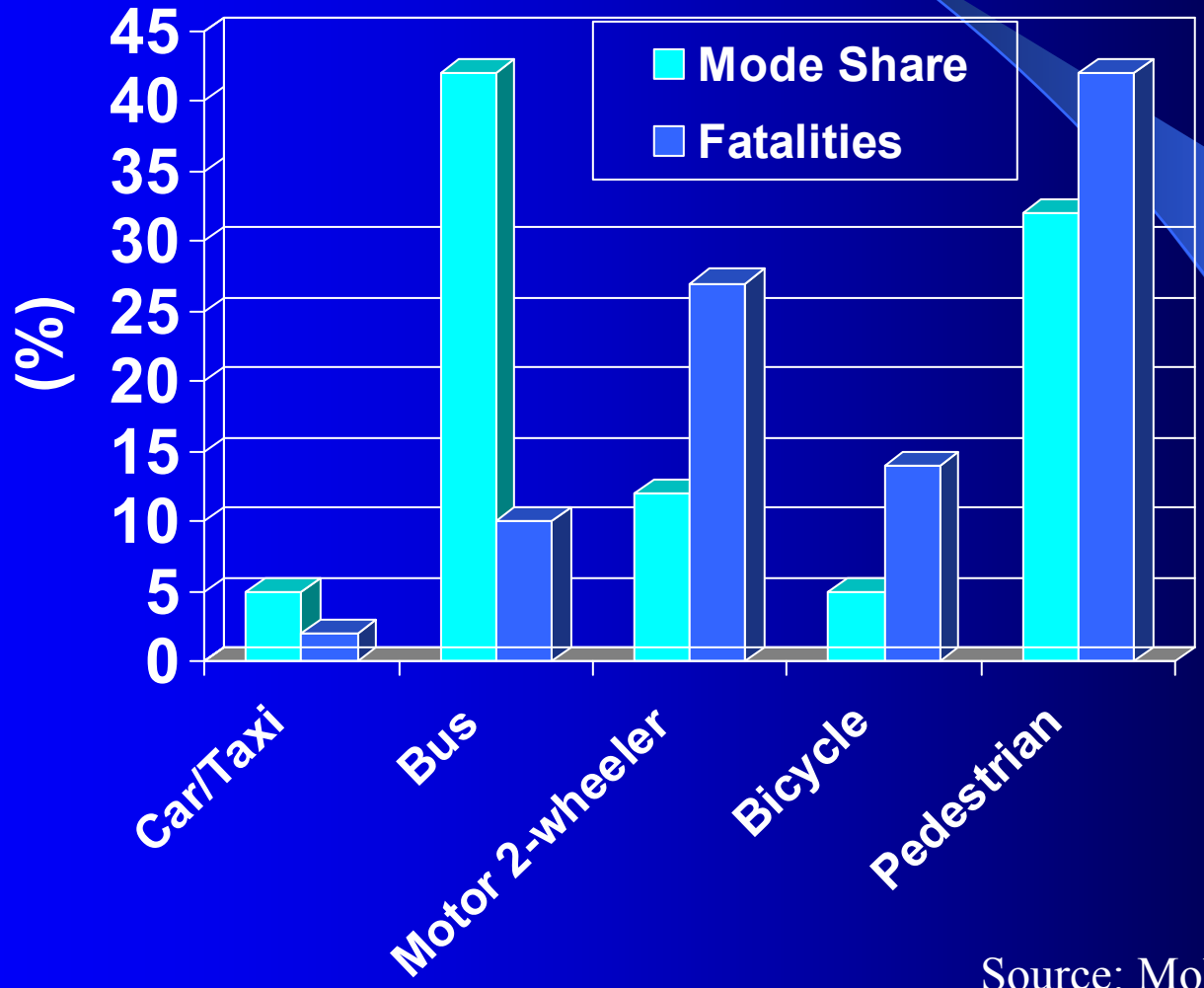
# Comparative Traffic Fatalities

| | Year | Fatalities | Fatalities/ 100,000 pop. | Fatalities/ 10,000 Veh. |
|---|---|---|---|---|
| Bangalore | 1995 | 678 | 16 | 10 |
| Bogota | 1996 | 1,073 | 17 | 19 |
| Delhi | 1993 | 1,783 | 21 | 9 |
| Durban | 1996 | 637 | 30 | 16 |
| Harare | 1998 | 391 | 23 | 10 |
| Mexico City | 1993 | 2,179 | 13 | 6 |
| Santiago | 1994 | 394 | 7 | 6 |
| São Paulo | 1991 | 2,715 | 17 | 7.9 |
| *United States* | *1995* | *42,000* | *16* | *3* |
| *Japan* | *1984* | *9,262* | *8* | *2* |

Sources: WBCSD, 2001; Vasconcellos, 2001; Vasconcellos, 1996.

# Equity - Accidents

## Delhi, 1994




Source: Mohan & Tiwari, 1999.

# Economic/Financial Sustainability

- **Mobility serves as key "lubricant" (providing *accessibility*) to sustaining our economic systems**

- **Limited resources available to dedicate to mobility demands**
  - Individuals and Firms have limited time & budgets
  - Financing for infrastructure and necessary institutions competes with other public needs
  - Space for infrastructure is limited
  - Energy resources are finite

# Congestion and The Three E's

- **Economically** – lost time for travellers/freight, lost resources (fuel) and often distorted investment decisions, reduced urban agglomeration economies
- **Socially** – poor are most often disproportionately burdened (public transport suffers), social networks (families) hampered
- **Environmentally** – air pollutant emissions increased, fuel consumption increased, urban expansion (sprawl) accelerated

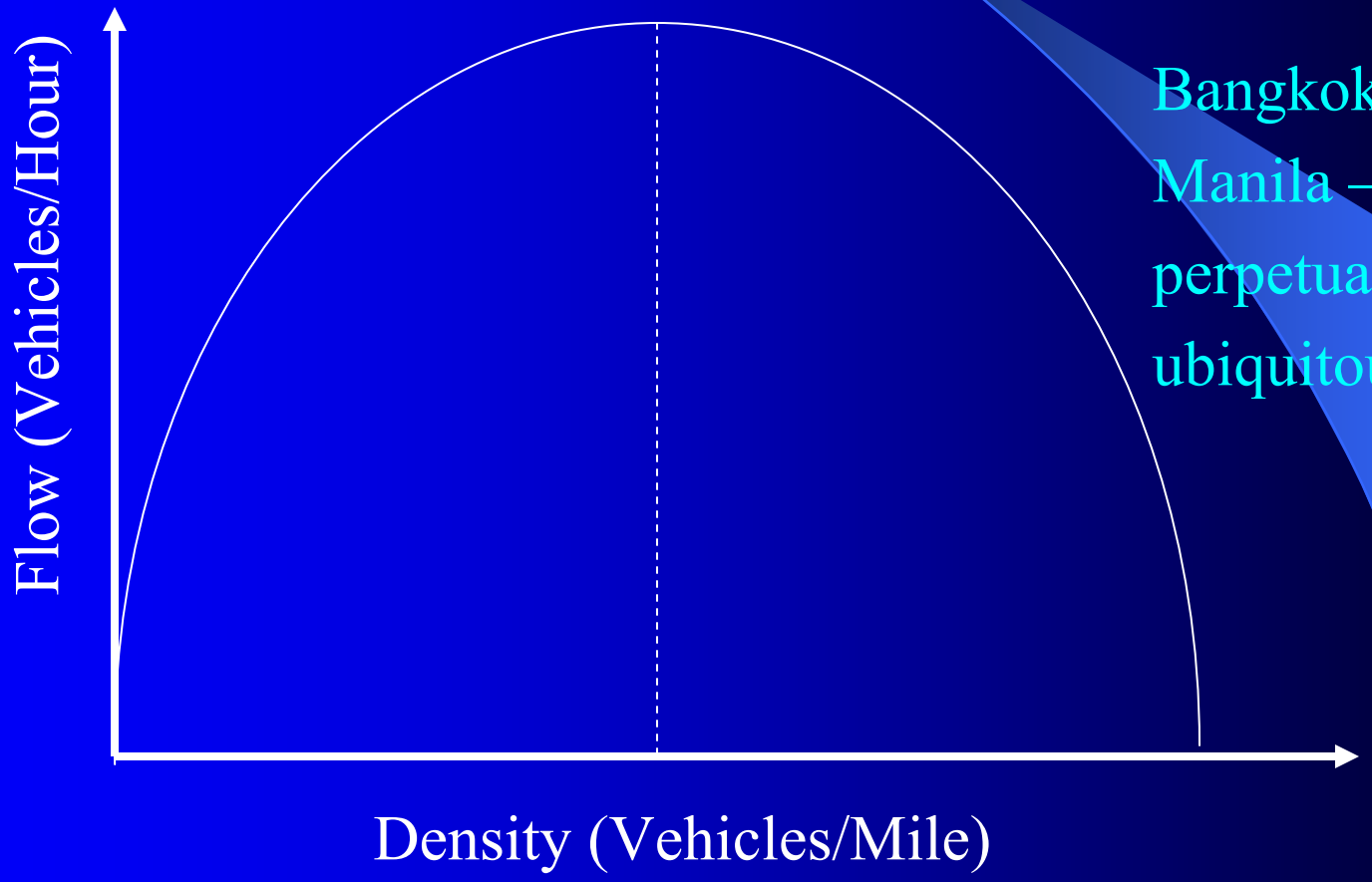
# Congestion Conditions

- Reflected in slow travel speeds and – at least partially – in high total travel times in developing country cities
  - Avg. peak-period travel speed in Bangkok, Manila, Mexico City: 10 km/hr
  - Avg. trip time in Manila, 120 minutes; Jakarta, 82 minutes
  - Not necessarily increasing in intensity, but almost certainly in time and space
- Anecdotal "evidence" abounds, but accurately comparing congestion levels across developing country cities is difficult due to lack of relevant data

# Congestion Perspectives

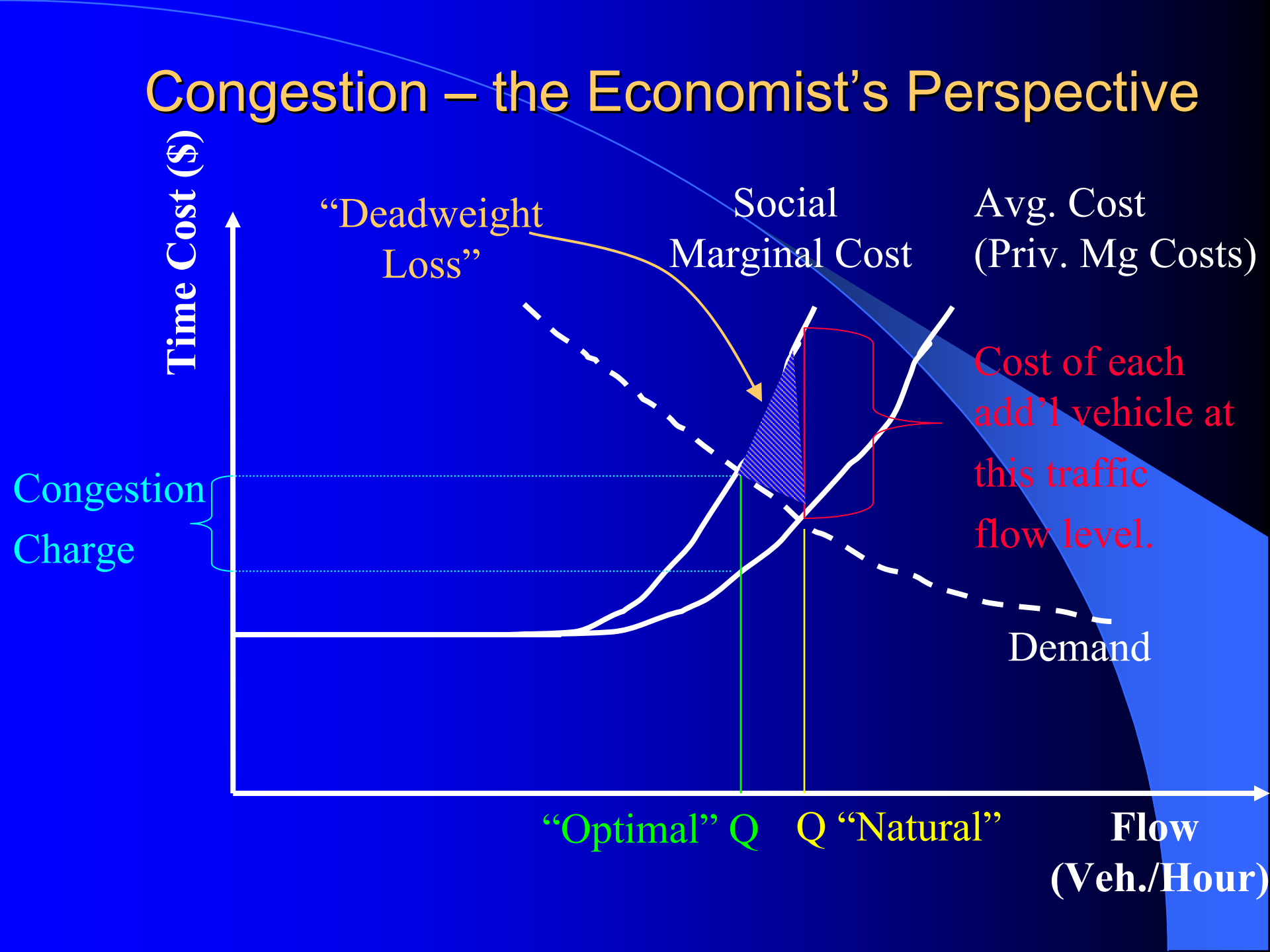
- *User* – speed reduced due to other road users
- *Engineers* – when traffic density reaches point where flow goes below design capacity
- *Administrators* – when a relatively arbitrary threshold (i.e., level of service) is exceeded
- *Economists* – individual average private cost exceeds the social marginal costs (externality)
- *Physicists* – non-linear, chaotic system in which small, random fluctuations can cause extended flow breakdowns (http://www.theatlantic.com/issues/2000/12/budiansky.htm)

# Congestion – the Engineer's Perspective




Bangkok, Jakarta, Manila – perpetually & ubiquitously here

# Congestion – the Economist's Perspective



# Economic Sustainability – Infrastructure and Finance

- Infrastructure's Dueling Pressures
  - Maintenance and management to make best use of existing infrastructure
  - Expansion to satisfy growth in motorized vehicles, travel demand, urban outgrowth
- Infrastructure "opportunity costs"
  - Of urban land
  - Of financial resources

# Economic Sustainability and Finance

- Relevant Expenditures
  - Construction, Maintenance, Management, Planning, Service Provision
- Relevant Revenue Sources
  - Vehicle Registrations Fees (buoyant due to motorization), Dedicated Fuel Taxes, Fares, Property Taxes, Other Taxes
- Challenges
  - Other public policy objectives: i.e., Income Redistribution
  - Multi-level authorities: national, regional, local
  - Unclear financing principles
  - Lack of marginal cost pricing, fees not matched with costs: “excess” demand, inability to plan “rationally”

# Environmental/Ecological Sustainability

- **Air/water/land pollution**
  - A major source of local air pollution & most rapidly growing source of global air pollution
  - Groundwater run-off, hydrologic impacts of paving
- **Noise pollution/vibration & aesthetics**
  - Disruption and damage in urban/suburban areas and rural & “wild” settings
  - Visual “intrusion”
- **Depletion of natural resources and ecosystem changes**
  - Loss of wetlands, infrastructure-induced land use changes, partition of habitats, etc.
- **Vehicle and parts disposal**

# Environment – Local Air Pollution

| Pollutant | What | Cause | Where | Health Effect |
|---|---|---|---|---|
| Carbon Monoxide (CO) | Odorless, Colorless Gas | Incomplete fuel combustion | Concentrated at local level – dense traffic | Reduced blood oxygen – dizziness, discomfort, death |
| Nitrogen Oxides (NOx) | Red-Brown, pungent | High temperature combustion | Local and atmospheric | Respiratory ailments & ozone precursors |
| Hydrocarbons (HCs or VOCs) | Various compounds | Incomplete combustion, evaporation | Local and atmospheric | Toxic, carcinogenic & ozone precursors |
| Lead | Vapor and Particulate | Lead added to gasoline | Local (primarily) | Growth retardation, hypertension, mortality |
| Sulfur Dioxide ($SO_2$) | Colorless Gas | Sulfur content of fuel | Local and atmospheric | Respiratory ailments, morbidity/ mortality |
| Particulate Matter (TSP, PM, $PM_{10}$, $PM_{2.5}$) | Solids, liquids | Road dust, combustion soot, 2ndary reactions | Local and atmospheric | Respiratory ailments, morbidity/ mortality, carcinogenic |
| Ozone | Atmospheric compound | Photochemical reaction – HCs & NOx | Atmospheric | Lung damage, respiratory/eye irritation |

# Transportation % Contribution to Local Air Pollutants

| City | Year | CO | HC | NOx | SOx | SPM |
|---|---|---|---|---|---|---|
| Beijing | 2000 | 84 | NA | 73 | NA | NA |
| Budapest | 1987 | 81 | 75 | 57 | 12 | NA |
| Cochin | 1993 | 70 | 95 | 77 | NA | NA |
| Delhi | 1987 | 90 | 85 | 59 | 13 | 37 |
| Lagos | 1988 | 91 | 20 | 62 | 27 | 69 |
| Mexico City | 1996 | 99 | 33 | 77 | 21 | 26* |
| Santiago | 1997 | 92 | 46† | 71 | 15 | 86‡ |
| São Paulo | 1990 | 94 | 89 | 92 | 64 | 39 |

*PM10; † Does not include evaporative emissions ‡ PM10, including road dust.

Source: WBCSD, 2001.

# Pollution Concentrations/Exposure

- Determine ultimate health impacts
- Influenced by
  - Meteorology – wind, sunshine, precipitation, temperatures (thermal inversion)
  - Physical characteristics – altitude (combustion), topographical (valleys), buildings ("man-made valleys)
  - Population and activity locations and densities

# Environment – Global Pollution

- Greenhouse Gas (GHG) Emissions & Climate Change
  - Carbon Dioxide (CO2), Methane, Nitrous Oxides, CFCs
  - Worldwide, transportation accounts for 26% of CO2 (17% road sector)
  - Transport most rapidly growing anthropogenic source
  - Transport nearly completely dependent on fossil fuels
  - Developing countries currently 25% of transportation GHGs, but growing rapidly

# Transport Emissions Determinants

**Emissions** = **Activities** (pkm or tonne-km) x **Mode Share** (% pkm or tonne-km) x **Fuel Intensity** (liters per pkm or tonne-km) x **Fuel Choice** (emission per liter)

**Activities** (pkm or tonne-km)

Determinants:

- Number of Trips
- Distance of Trips
- Urban Density
- Population
- Demographics
- Income
- ….

**Mode Share** (% pkm or tonne-km)

Determinants:

- Income
- Motorization rate
- Infrastructure Conditions
- Service Provision
- Relative Travel Conditions
- ….

**Fuel Intensity** (liters per pkm or tonne-km)

Determinants:

- Fuel Efficiency
- Engine Type
- Vehicle Load
- Vehicle Age
- Congestion Levels
- Capacity Mix
- Road Conditions
- …

**Fuel Choice** (emission per liter)

Determinants:

- Fuel type
- Fuel Quality
- Engine Type
- Vehicle Technology
- Vehicle Age
- Temperature
- Altitude
- ….

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

# Relative Contribution by Vehicle Type

## Santiago – 1998 (Percentage of Total Pollutants)

| 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

# Relative Contribution by Vehicle Type

## Mexico City – 1996 (Percentage of Total Pollutants)

| Vehicle Type | $PM_{10}$ | CO | NOx | VOCs | $SO_2$ |
|---|---|---|---|---|---|
| Cars and Light Trucks | 2 | 44 | 20 | 13 | 8 |
| Taxis | 0.5 | 10 | 5 | 3 | 2 |
| Trucks | 21 | 34 | 46 | 14 | 9 |
| Buses | 1.8 | 0.2 | 3 | 0.3 | 0.4 |
| Colectivos | 0.2 | 11 | 4 | 3 | 1 |
| All Vehicle Types | 26 | 99 | 77 | 33 | 20 |

Source: CAM, 1999

# Index of Pollutant Contribution per Vehicle - Santiago

| Vehicle Type | $PM_{10}$ | CO | NOx | VOCs | $SO_2$ |
|---|---|---|---|---|---|
| Cars and Light Trucks | 0.015 | 0.833 | 0.391 | 0.394 | 0.038 |
| Taxis | 0.022 | 1.780 | 0.756 | 0.812 | 0.089 |
| Trucks | 0.48 | 1.64 | 4.23 | 0.94 | 1.35 |
| Buses | 1.77 | 1.25 | 7.88 | 1.34 | 3.00 |
| Motorcycles | 0.0 | 0.2 | 0.0 | 0.2 | 0.0 |

Index based on relative contribution of pollution (vehicle share of total pollutants) and relative number of vehicles. Sources: CONAMA, 1998; INE, 1998.

# Index of Pollutant Contribution per Vehicle – Mexico City

| Vehicle Type | $PM_{10}$ | CO | NOx | VOCs | $SO_2$ |
|---|---|---|---|---|---|
| Cars and Light Trucks | 0.03 | 0.52 | 0.23 | 0.15 | 0.09 |
| Taxis | 0.68 | 13 | 5.79 | 3.75 | 2.32 |
| Trucks | 1.85 | 3.04 | 4.11 | 1.20 | 0.81 |
| Buses | 7.5 | 0.94 | 13 | 1.33 | 1.55 |
| Colectivos | 0.07 | 3.15 | 1.10 | 0.98 | 0.29 |

Index based on relative contribution of pollution (vehicle share of total pollutants) and relative number of vehicles. Source: Zegras et al, 2000.

# Index of Pollutant Contribution per Vehicle - Interpretations

- Santiago and Mexico City
  - Poor emissions characteristics of buses, taxis and trucks, and/or
  - their relatively intensive use (high VKT).

# Index of Relative "Work Efficiency" – Mexico City

| Vehicle Type | $PM_{10}$ | CO | NOx | VOCs | $SO_2$ |
|---|---|---|---|---|---|
| Cars and Light Trucks | 0.11 | 2.23 | 0.99 | 0.64 | 0.40 |
| Taxis | 0.18 | 3.39 | 1.51 | 0.98 | 0.61 |
| Buses | 0.15 | 0.02 | 0.26 | 0.03 | 0.03 |
| Colectivos | 0.00 | 0.16 | 0.06 | 0.05 | 0.02 |

This index is based on relative contribution of pollution (vehicle share of total MCMA pollutants) and mode share of all motorized, road-based trips.
Source: Zegras et al, 2000.

# Index of Relative "Work Efficiency" - Interpretations

- Colectivos
  - Despite their large number, these vehicles exhibit a very low index of pollution per passenger trip share, suggesting high passenger utilization rates.
- Taxis
  - High relative pollution likely derives from their relatively low occupancy rates and the fact that they spend much time driving without any passengers.
- Cars
  - High relative pollution index comes from their relatively low occupancy rates.

# Noise Pollution

- Transportation often major source
  - Scarce data
- Santiago, late 1980s
  - 80% of population living or working on major transport arteries suffered risk of hearing loss.
- Lima, mid-1990s
  - On principal avenues, noise levels 2 times higher than norms
- Affects property values, may accelerate decentralization
  - Policy dilemma: buses often a major culprit

# Other Environmental Impacts

- Induced consumption of open space
  - Again, “does transport cause sprawl?”
- Infrastructure destruction of delicate ecosystems
- Runoff from highway pavement
- Vehicle disposal, fuel leakage, etc.

# Urban Transport Sustainability: Some Key Issues

- **Energy Systems**
  - Petroleum accounts for 96% of transportation energy use, likely to remain dominant in medium term
  - Price fluctuations, OPEC dominance, add considerable uncertainty/instability to supply conditions
  - Imports pose significant hard currency costs on poorer countries
  - Projected growth in road transport fuels: 3.7-4.2% in developing world; 1.3%-1.5% in industrialized
- **Environmental Impacts**
  - Technology has shown to significantly reduce per unit local air pollution impacts – at what cost, especially among the poorer;
  - global air pollution problem more elusive due to petroleum dependency;
  - additional ecological impacts are less well-understood, due to complexity, but likely significant

# Urban Transport Sustainability: Some Key Issues

- **Financial Systems**
  - Mechanisms proven for "sustainable" infrastructure financing (including via privatization)
  - Institutional Barriers to implementing effective financing systems
  - Persistently difficult issues related to financing public transport operations (and rail transit development)
  - Ongoing challenge of charging external costs
- **Broader Social Issues**
  - Can mobility strategies be deployed to improve equity in distribution of opportunities (accessibility
  - Accidents still major public health threat

# How Would You "Measure" the Principles?

| Measure/Indicator | Principle | Desired Direction |
|---|---|---|
| Accessibility | Economic | ↑ |
| Equity in Access | Equity | ↑ |
| Adequate Infrastructure | Economic/Equity | ↑ |
| Freight Transport | Economic | ↑ |
| Congestion | Economic/Equity/Environment | ↑ |
| Urban Air Emissions | Environment | ↓ |
| Greenhouse Gas Emissions | Environment | ↓ |
| Transportation Noise | Environment | ↓ |
| Land, Water, Ecosystem Impacts | Environment | ↓ |
| Community Disruption | Equity/Economic | ↓ |
| Accidents | Equity/Economic | ↓ |
| Non-Renewable Resource Use | Environment/Economic | ↓ |
| Solid Waste | Environment | ↓ |

# Assignment 2

In class and in the readings we have seen the broad-range of impacts of urban transportation and their implications for sustainability. We have also been introduced to some of the possible interventions for improving transportation system performance as it relates to sustainability.

Identify two of the most pressing needs related to urban transportation and sustainability in the Latin America context. Justify your selection of these needs relative to others. What interventions would you recommend to address these needs? Why?

No lengthy introductions or conclusions are necessary, rather:
Pressing Need.
Why? Relative to others.
Based on What criteria?
Thoughts on Intervention.

This can be done in 4 paragraphs. 1.5 pages Max.