Chapter 8
More on Transportation

Lecture #19
HNRS 228
Energy and the Environment
Adapted from University of Wisconsin
at Green Bay and George Mason
University, Engineering (Lakshmanan)
Remember Overview of Chapter 8

- Transportation
  - Power and Energy
    - Batteries, flywheels, hybrids, hydrogen, alcohol
  - Traffic safety
  - The Automobile
  - Mass Transportation
What is the work output of a heat engine whose thermal energy input is 400 J and whose exhaust is 300 J?

- A 100 J
- B 200 J
- C 300 J
- D 400 J
- E 700 J

Work output = Energy Input - Exhaust (or waste)
Work output = 400 - 300 = 100 J
iClicker Question

You have a heat engine whose thermal energy input is 400 J and whose exhaust is 300 J, what is the efficiency of this heat engine?

A 175%
B 75%
C 50%
D 33%
E 25%

Efficiency = work output / energy input
= 100 / 400
= 25%
iClicker Question

During each cycle of its operation, a certain heat engine does 40 joules of work while exhausting 160 joules of thermal energy to the environment. The energy efficiency of this heat engine is

A 20%
B 25%
C 75%
D 80%
E None of the above.

Energy efficiency = Work output / Energy input
= 40 J / (40 J + 160 J)
= 40 J / 200 J
= 20%

Please do not forget that the energy input = work output + exhaust [because of the conservation of energy]
A 2000 N car travels 50 m along a level road, powered by a drive force of 1000 N. The work done by the drive force is

A 5000 J  
B 1000 J  
C 2000 J  
D 50,000 J  
E 10,000 J

\[ W = F \times d = (1000 \text{ N}) \times (50 \text{ m}) = 50,000 \text{ J} \]
iClicker Question

• What does HEV stand for?
  - A  High Efficiency Vehicle
  - B  Heavy Economy Vehicle
  - C  Hybrid Electric Vehicle
  - D  High-voltage Electric Vehicle
  - E  High Energy Vehicle
iClicker Question

Which of the following does not increase fuel efficiency?

- A  Properly inflated tires
- B  Proper oil used
- C  Weight of cargo
- D  Driving faster
- E  Lighter weight vehicle
iClicker Question

• What does CAFE stand for?
  - A Combined Average Fuel Economy
  - B Corporate Average Fuel Economy
  - C Composite Average Fuel Economy
  - D Calculated Average Fuel Estimate
  - E Corporate Average Fuel Estimate
## Transportation Time Through the Centuries

<table>
<thead>
<tr>
<th></th>
<th>1700</th>
<th>1800</th>
<th>1900</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel across Atlantic</td>
<td>Weeks</td>
<td>Weeks</td>
<td>Days</td>
<td>Hours</td>
</tr>
<tr>
<td>Travel across U.S.</td>
<td>Months</td>
<td>Months</td>
<td>Days</td>
<td>Hours</td>
</tr>
<tr>
<td>Communication across Atlantic</td>
<td>Weeks</td>
<td>Weeks</td>
<td>“Instant”</td>
<td>“Instant”</td>
</tr>
</tbody>
</table>
Inventions 1800-1900

- Steamship, 1807
- Telegraph 1837
- Automobile 1884
- Bicycle 1885
- Camera (film) 1888
- Dynamite 1866
- Dynamo 1871
- Elevator, 1852
- Electric Iron 1882
- Electric Motor 1837
- Phonograph 1877
- Typewriter 1867
- Welding 1877
- Sewing Machine 1846
- Light Bulb 1879
- Telephone 1876
- Blast Furnace 1856
- Electric Stove 1896
Overcoming limitations

- Limitations of Space
  - Distance
- Limitations of Time
  - Food Preservation
  - Communications
  - Lighting
  - Rapid Production
  - Growth of Leisure
Lighting in Early 1800's

- Coal + Heat => Coking
- Coking, originally developed on a large scale for steel making, gives off
  - Liquid Fuels
  - Gases
- Coking gases lead to piped gas Lamps.
  - Demand for gas soon leads to a gas industry in its own right
Lighting into the 1900s

- **1830 Whale Oil**
  - Except in cities, America too dispersed for piped gas. Need for portable high-quality fuel answered by whale oil.
- **1860 Kerosene Lamp**
  - Kerosene developed as a substitute for increasingly scarce whale oil.
- **1876 Electric Light**
- **1920 Bulb-blowing Machinery**
  - Brought light bulbs down in cost from dollars to pennies. One of the oldest unchanged mass-production devices.
Social Impact of Lighting
---------------------------------
Especially on Transportation

- **Community life**
  - Safer to go out at night
  - Places to go
    - theaters, social gatherings, etc.
- **More Effective Use of Leisure Time**
  - Easier to Read
  - Adult Education for Working Classes
- **Demand for more Leisure Time**
The Role of Communications

----------------------
Especially on Transportation

• You can’t have skyscrapers without telephones
• Mail delivery financed transportation technology
  - Humans, humans on horses, horse drawn carriages
  - Railroads, 19th Century
  - Air Travel, 20th Century
Effects of Overcoming Space and Time

- Faster transportation leads to
  - More Leisure Time
  - More Effective Use of Leisure
  - More Experiences
- Space = Time if you have to move slowly
  - Railroad (Bulk Transport)
  - Personal Transportation
  - Air (Personal and Cargo)
Transportation Using Canals

- Early 1800's Canals in England
- 1825 Erie Canal: Access to Great Lakes and West
- 1856 Soo Canal: Iron to feed U.S. steel industry

- The age of canals was short and canals don't look very impressive on the map, but they were a critical link in transportation history
Transportation by Railroad

- 1800 Prototypes in Mines
- 1829 Manchester-Liverpool, England
- 1835 1000 Miles in US
- 1840 3000 Miles in US
- 1860 30,000 Miles in US
- 1869 Transcontinental
Effects of the Railroad

• Opening of Markets
• Rise of Consumer Goods
• Exploitation of European Colonies
  -but-
  - Led to Third World (especially India) Rail Systems
Travel Time in the USA, 1800
Travel time in the USA, 1830
Travel time in the USA, 1857
iClicker Question

• In 1800 what was the average time to go from New York to Chicago?
  - A 1 day
  - B 1 week
  - C 2 weeks
  - D 3 weeks
  - E over 4 weeks
iClicker Question

• In 1857 what was the average time to go from New York to Chicago?
  - A 1 day
  - B 2 days
  - C 5 days
  - D 7 days
  - E 2 weeks
iClicker Question

- What was the major transportation change that lowered the time taken to go from New York to Chicago between 1800 and 1857?
  - A  the development of canals
  - B  the invention of the wheel
  - C  the horse drawn carriage
  - D  the automobile
  - E  the railroad
Where the Rails Met
Union Pacific Cut
The Rival Routes
What Happened to the Rails

After the opening of the Lucin Cutoff in 1904 the historic rail line north of the Great Salt Lake was of minimal importance. After four additional decades of modest use, here in 1942 the last spike was ceremonially "undriven" before a crowd of UP, SP, and state dignitaries. In a few months the entire line between Corinne and Lucin was salvaged, with the steel directed to America's war effort.
Not Far Away...
Travel times in the USA, 1930

Travel Times
From New York
1930 (By Rall)

3 Days

2 Days

1 Day
Effects of Overcoming Space/Distance

- **Manufacturer**
  - Access to Raw Materials

- **Seller**
  - Access to Markets

- **Consumer**
  - Access to Goods
Urban Sprawl

- Steamboat suburbs, 1830’s
- Railroad suburbs by 1850’s
- “Commuter” - 1865
- Planned suburbs, late 1800’s
- Streetcars and Interurban railroads
After World War II, there was an enormous spread of suburban growth. The sequence of growth was one of radial expansion along urban expressways, followed by a filling-in of the areas between them. Freeways and beltways fostered the development of suburban centers that competed with the central business district as places of employment and locations for commercial, financial, and professional services.
During the mid-1800's, urban growth spread along the radial routes of the early streetcars. Residential growth spread northward along Lake Michigan and to the northwest. The lines of urban expansion set the initial structure for the development of metropolitan Chicago.
The introduction of the electric streetcar reinforced the radial pattern of growth for the city. By 1900, the radial patterns were less pronounced as a result of residential growth in the interstitial areas.
Wisconsin Interurban Railroads
Midwest Interurban Railroads
Interurban Rail, Los Angeles
Los Angeles Streetcar Lines
Los Angeles doesn't sprawl because it has freeways
--
Los Angeles built freeways because it sprawls
iClicker Question

- Urban sprawl began after World War II.
  - A True
  - B False
iClicker Question

• The automobile was the major cause of urban sprawl.
  - A True
  - B False
The Downside of Light Rail

- Lines were very unprofitable
- Owners invested in real estate
- Sometimes built amusement parks at the end of the line
- Lines frequently serviced owners’ developments and bypassed others
If You Think Cars Pollute, Consider Horses

- New York City generated thousands of tons of horse manure a day
- Horses often cruelly overworked
- 15,000 horses a year died on the streets of New York each year
- Many were just abandoned
Roads

- 1790: Nicolas Cugnot, prototype steam carriage
- 1800’s: Thomas Telford
  - Old-style roads damaged by wheels
  - Well-graded roads damaged by horses’ hooves
- By 1830’s, Britain had road system
  ✷ better than the Roman Empire
More on Roads

- Telford advocated steam carriages to reduce wear on roads
- Prototypes actually ran in 1830’s
- Stiff opposition from stagecoach operators, who held mail contracts
- Stagecoach operators eventually eclipsed by railroads
- Delayed advent of auto by half century
Personal Transportation

- Bicycle: toy for rich in 1830’s
- Fully modern design by 1880’s
- First true personal transportation
  - Not bound by streetcar routes
  - Doesn’t need to be fed
- Pioneered mass production technology and metallurgy for automobile
Another Technological Spiral
George B. Selden
“Inventor” of the Automobile

- Foresaw mechanized transport coming
- Took out a patent in 1879 on a largely imaginary “road engine”
- Delayed issuance of the patent for 16 years (1895)
- Collected royalties for 17 years despite doing nothing for the technology
- Selden’s gimmick led to reforms in patenting
1883 Stationary Gas Engine
Early Motorcycle, 1885
1889 Daimler Auto
1902 Daimler Roadster
Mercedes Jellinek
iClicker Question

- Daimler invented the automobile.
  - A True
  - B False
World War I

- Railroads insufficient for Army's needs
- Army turned to truck convoys
- Civilians found convoy routes featured innovations
  - Route Markings
  - Regular Maintenance
  - Snow Removal
Pershing's Map, 1922
The Interstate Highway System
World War II: The First High-Tech War

First war whose outcome depended critically on simultaneous technological advances

- Radar
- Computers
- Missiles
- Jet Aircraft
- Nuclear Weapons
Post-War Political Changes

- Military-Industrial Complex
- Cold-War

Post-War Lifestyle Changes

- Growth of Suburbs
- Professionalization
  - GI Bill
  - Growth of Universities
    - Overtraining?
- Rise of Materialism
- Erosion of Family?
Much of Today's "High Tech" is an improvement on older "Low Tech."

In many ways, the "Low Tech" advance was the real revolution

• Freeway vs. Railroad
• Light Bulb vs. Gas Lamp
• Internal Combustion or Electric Motor vs. Steam
• Automobile vs. Bicycle
The Rising Need for Mass Transportation
Urban Population in Industrial & Developing Regions, Selected Years

Billion People

- **Industrial**
- **Developing**

Year: 1950, 1975, 1995, 2030
### Rate and Scale of Population Growth in Selected Industrial Cities, 1875-1900, and Developing Cities, 1975-2000

<table>
<thead>
<tr>
<th>City</th>
<th>Annual Population Growth (percent)</th>
<th>Population Added (million)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industrial Cities (1875-1900)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicago</td>
<td>6.0</td>
<td>1.3</td>
</tr>
<tr>
<td>New York</td>
<td>3.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Tokyo</td>
<td>2.6</td>
<td>0.7</td>
</tr>
<tr>
<td>London</td>
<td>1.7</td>
<td>2.2</td>
</tr>
<tr>
<td>Paris</td>
<td>1.6</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>Developing Cities (1975-2000)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lagos</td>
<td>5.8</td>
<td>10.2</td>
</tr>
<tr>
<td>Bombay</td>
<td>4.0</td>
<td>11.2</td>
</tr>
<tr>
<td>São Paolo</td>
<td>2.3</td>
<td>7.7</td>
</tr>
<tr>
<td>Mexico City</td>
<td>1.9</td>
<td>6.9</td>
</tr>
<tr>
<td>Shanghai</td>
<td>0.9</td>
<td>2.7</td>
</tr>
</tbody>
</table>
Trends Affecting Transportation

A. Economics and Society
   ♦ Concentration & Dispersal

B. Rapid Urbanization & Explosion of Motorization

C. Changing Nature of Travel

D. Problems of Auto-dependent World
   ♦ Congestion
   ♦ Pollution
   ♦ Add to Global Climate Change
   ♦ Traffic Accidents
   ♦ Other Social Costs

E. Implications for Mass Transportation
Automotive Dependence

- Use of automobiles*
- Total population
- Urban population
- Motor vehicle fleet
Road Supply as a Percentage of Urbanized Areas

<table>
<thead>
<tr>
<th>City</th>
<th>Road Space (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Developing Countries</strong></td>
<td></td>
</tr>
<tr>
<td>Kolkata (India)</td>
<td>6.4</td>
</tr>
<tr>
<td>Shanghai (China)</td>
<td>7.4</td>
</tr>
<tr>
<td>Bangkok (Thailand)</td>
<td>11.4</td>
</tr>
<tr>
<td>Seoul (S. Korea)</td>
<td>20.0</td>
</tr>
<tr>
<td>Delhi (India)</td>
<td>21.0</td>
</tr>
<tr>
<td>São Paulo (Brazil)</td>
<td>21.0</td>
</tr>
<tr>
<td><strong>Developed Countries</strong></td>
<td></td>
</tr>
<tr>
<td>New York (US)</td>
<td>22.0</td>
</tr>
<tr>
<td>London (UK)</td>
<td>23.0</td>
</tr>
<tr>
<td>Tokyo (Japan)</td>
<td>24.0</td>
</tr>
<tr>
<td>Paris (France)</td>
<td>25.0</td>
</tr>
</tbody>
</table>
### Global Car Ownership, 1993

<table>
<thead>
<tr>
<th>Region</th>
<th>Cars/1000 pop</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Asia</td>
<td>3</td>
</tr>
<tr>
<td>Africa</td>
<td>14</td>
</tr>
<tr>
<td>East Asia &amp; Pacific</td>
<td>29</td>
</tr>
<tr>
<td>Middle East</td>
<td>45</td>
</tr>
<tr>
<td>Latin America &amp; Caribbean</td>
<td>68</td>
</tr>
<tr>
<td>Central &amp; Eastern Europe</td>
<td>72</td>
</tr>
<tr>
<td>OECD (excluding the US)</td>
<td>366</td>
</tr>
<tr>
<td>US</td>
<td>561</td>
</tr>
</tbody>
</table>
## Global Vehicle Ownership, Selected Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>GNP/capita (US$)</th>
<th>Veh/1000 pop</th>
<th>Private motorized vehicles (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MTW</td>
<td>Cars</td>
</tr>
<tr>
<td>Japan</td>
<td>34630</td>
<td>640</td>
<td>20</td>
</tr>
<tr>
<td>US</td>
<td>24780</td>
<td>740</td>
<td>2</td>
</tr>
<tr>
<td>Germany</td>
<td>23980</td>
<td>570</td>
<td>9</td>
</tr>
<tr>
<td>France</td>
<td>23420</td>
<td>520</td>
<td>10</td>
</tr>
<tr>
<td>UK</td>
<td>18340</td>
<td>410</td>
<td>3</td>
</tr>
<tr>
<td>Australia</td>
<td>18000</td>
<td>610</td>
<td>3</td>
</tr>
<tr>
<td>S. Korea</td>
<td>8260</td>
<td>206</td>
<td>24</td>
</tr>
<tr>
<td>Brazil</td>
<td>4400</td>
<td>190</td>
<td>10</td>
</tr>
<tr>
<td>Malaysia</td>
<td>3140</td>
<td>340</td>
<td>56</td>
</tr>
<tr>
<td>Thailand</td>
<td>2140</td>
<td>190</td>
<td>66</td>
</tr>
<tr>
<td>The Philippines</td>
<td>950</td>
<td>32</td>
<td>26</td>
</tr>
<tr>
<td>Indonesia</td>
<td>810</td>
<td>58</td>
<td>69</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>600</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>China</td>
<td>530</td>
<td>21</td>
<td>40</td>
</tr>
<tr>
<td>India</td>
<td>320</td>
<td>30</td>
<td>67</td>
</tr>
<tr>
<td>Vietnam</td>
<td>210</td>
<td>27</td>
<td>91</td>
</tr>
</tbody>
</table>
Daily Motorized Trips by Public & Private Transport, Selected Cities in Developing Countries

City
- Beijing
- Bouake
- Rio
- Abdijan
- Santiago
- Colombo
- Seoul
- Cairo
- Mexico City
- Buenos Aires
- Pretoria
- Dakar
- Lagos
- Caracas
- Douala
- Sao Paulo
- Yaounde
- Bamako
- Hanoi
- Ouagadougou

% of Daily Trips

- Public
- Private
# Trip Purpose, Selected Cities

<table>
<thead>
<tr>
<th>City (country)</th>
<th>Trip Purpose %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Work</td>
</tr>
<tr>
<td>Alger (Algeria)</td>
<td>25</td>
</tr>
<tr>
<td>Bangkok (Thailand)</td>
<td>34</td>
</tr>
<tr>
<td>Kolkata (India)</td>
<td>44</td>
</tr>
<tr>
<td>Delhi (India)</td>
<td>46</td>
</tr>
<tr>
<td>Hanoi (Vietnam)</td>
<td>45</td>
</tr>
<tr>
<td>Jakarta (Indonesia)</td>
<td>39</td>
</tr>
<tr>
<td>Santiago (Chile)</td>
<td>36</td>
</tr>
<tr>
<td>São Paulo (Brazil)</td>
<td>41</td>
</tr>
</tbody>
</table>
## Door to Door Travel Times, all Modes, São Paulo, 1997

<table>
<thead>
<tr>
<th>Mode</th>
<th>Door-to-door travel time (min) (including transfers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train</td>
<td>93</td>
</tr>
<tr>
<td>Subway</td>
<td>77</td>
</tr>
<tr>
<td>Bus</td>
<td>56</td>
</tr>
<tr>
<td>Minibus¹</td>
<td>37</td>
</tr>
<tr>
<td>Auto</td>
<td>28</td>
</tr>
<tr>
<td>Taxi²</td>
<td>26</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>25</td>
</tr>
<tr>
<td>Bike</td>
<td>23</td>
</tr>
<tr>
<td>Foot</td>
<td>15</td>
</tr>
</tbody>
</table>

(1) illegal paratransit  
(2) individual use only  

source: CMSP, 1998
### Car and Bus Travel Times

<table>
<thead>
<tr>
<th>City (Country)</th>
<th>Bus</th>
<th>Car</th>
<th>Ratio bus/car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alger (Algeria), 1990</td>
<td>56</td>
<td>30</td>
<td>1.9</td>
</tr>
<tr>
<td>Caracas (Venezuela), 1982</td>
<td>54</td>
<td>36</td>
<td>1.5</td>
</tr>
<tr>
<td>Mexico City (Mexico), 1994</td>
<td>50</td>
<td>35</td>
<td>1.4</td>
</tr>
<tr>
<td>São Paulo (Brazil), 1997</td>
<td>56</td>
<td>28</td>
<td>2</td>
</tr>
</tbody>
</table>

(a) door-to-door travel times, average for all trips
## Traffic Fatalities and Rates, Selected Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Fatalities/year</th>
<th>Fatalities/10,000 veh</th>
<th>Fatalities/100,000 pop</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Developed</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US, 1995</td>
<td>41,798</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>France, 1984</td>
<td>11,685</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>Germany, 1984</td>
<td>10,199</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Japan, 1984</td>
<td>9,262</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td><strong>Developing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>India, 1996</td>
<td>69,800</td>
<td>21</td>
<td>8</td>
</tr>
<tr>
<td>China, 1994</td>
<td>66,322</td>
<td>82</td>
<td>6</td>
</tr>
<tr>
<td>Brazil, 1995</td>
<td>27,886</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>S. Korea, 1995</td>
<td>10,323</td>
<td>12</td>
<td>23</td>
</tr>
<tr>
<td>S. Africa, 1992</td>
<td>10,142</td>
<td>18</td>
<td>32</td>
</tr>
<tr>
<td>Nigeria, 1980</td>
<td>8,936</td>
<td>141</td>
<td>13</td>
</tr>
<tr>
<td>Thailand, 1992</td>
<td>8,184</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Poland, 992</td>
<td>6,946</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>Mexico, 1994</td>
<td>5,115</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Bangladesh, 1992</td>
<td>2,317</td>
<td>61</td>
<td>2</td>
</tr>
<tr>
<td>Czech Republic, 1997</td>
<td>1,600</td>
<td>4</td>
<td>15</td>
</tr>
</tbody>
</table>
Pedestrian Fatalities as a Percentage of Total Traffic Fatalities, Several Regions

<table>
<thead>
<tr>
<th>Region</th>
<th>Pedestrian Fatalities (% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe/ US</td>
<td>20</td>
</tr>
<tr>
<td>Latin America</td>
<td>60</td>
</tr>
<tr>
<td>Africa</td>
<td>45</td>
</tr>
<tr>
<td>Middle East</td>
<td>51</td>
</tr>
<tr>
<td>Asia</td>
<td>42</td>
</tr>
</tbody>
</table>
Transportation History Summary

~ The Horse Car Era (1840-90)
~ The Electric Street Car (1890 - 1920)
~ Interurban & Suburban Railroads (1900-1930)
~ Expressways & Beltways (1950 + )
Post World War II Transit

~ The Interstate Program
~ Home Mortgage Subsidy Program
~ The G. I. Bill
~ The Parking Policies
~ Increasing Female Labor Force Participation
~ The Decline of Transit
~ Public Support of Transit
Five major trends in public transit ridership are evident since 1900. A period of initial growth between 1890-1920, followed by a period of fluctuation between 1920-1939 during which an initial growth in ridership gave way to a decline during the Great Depression years. This loss in ridership was offset by dramatic growth during the war years 1940-1945. Ridership declined dramatically from 1946-1972 with the rapid suburbanization of metropolitan areas and a public preference for the automobile. The years from 1972 to the present have seen a modest increase in ridership as a result of growing awareness and support for alternatives to the automobile.
Share of Transit Trips in Large Metropolitan Areas, All Modes (a), and Rail Modes only (b), 1993.
Car Ownership Rate in Selected Countries, 1970-92 (number of cars per thousand persons)
Transportation Indicators in Selected Cities, by Regional Average, 1990

<table>
<thead>
<tr>
<th>Region</th>
<th>Driving</th>
<th>Public Transport (percent)</th>
<th>Walking/Cycling</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>86.4</td>
<td>9.0</td>
<td>4.6</td>
</tr>
<tr>
<td>Australia</td>
<td>80.4</td>
<td>14.5</td>
<td>5.1</td>
</tr>
<tr>
<td>Canada</td>
<td>74.1</td>
<td>19.7</td>
<td>6.2</td>
</tr>
<tr>
<td>Western Europe</td>
<td>42.8</td>
<td>38.8</td>
<td>18.4</td>
</tr>
<tr>
<td>Developing Asia</td>
<td>38.4</td>
<td>35.7</td>
<td>25.8</td>
</tr>
<tr>
<td>Wealthy Asia</td>
<td>20.1</td>
<td>59.6</td>
<td>20.3</td>
</tr>
</tbody>
</table>
Public Transportation

A. Formal and Informal Bus and Other Services
   - Decline of Large Bus Operations
     ♦ municipal and large by systems
     ♦ fare control, investment declines, poorer service
     ♦ corruption and political control
     ♦ failures: Lagos State Transportation Corporation
       Pakistan Road Transport Corporation
       Central Transport Board
   - Para Trasit Services

B. Urban Transit Options
   - Technology
   - Operational Form
   - Amenity Levels
   - Management Form
   - Costs
## Characteristics of Selected Light Rail Transit Systems

<table>
<thead>
<tr>
<th>City</th>
<th>Right-of-way: elevated elv underground: u/g</th>
<th>Length km</th>
<th>Station spacing km</th>
<th>Minimum headway Min:sec</th>
<th>Cars per train</th>
<th>Hourly design capacity p/h/d</th>
<th>Average journey speed kmph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogota</td>
<td>Elevated</td>
<td>50.0</td>
<td>1.0</td>
<td>5.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>At grade</td>
<td>23.0</td>
<td>0.6</td>
<td>1.00</td>
<td>1/2</td>
<td>14,000</td>
<td>26</td>
</tr>
<tr>
<td>Tuen Mun</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Istanbul</td>
<td>Part u/g part a/g</td>
<td>24.0</td>
<td>1.3</td>
<td>1:30</td>
<td>3/4</td>
<td>28,000</td>
<td>28</td>
</tr>
<tr>
<td>Manila</td>
<td>Elevated</td>
<td>14.0</td>
<td>1.2</td>
<td>2:00</td>
<td>2</td>
<td>25,000</td>
<td>28</td>
</tr>
<tr>
<td>Medellin</td>
<td>Elevated</td>
<td>32.0</td>
<td>1.3</td>
<td>2:30</td>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mexico City</td>
<td>Part a/g part elv</td>
<td>11.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tren leger</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rio Line 2</td>
<td>Part u/g part a/g</td>
<td>22.0</td>
<td>1.6</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tunis</td>
<td>At grade</td>
<td>10.0</td>
<td>0.8</td>
<td>1:00</td>
<td>2</td>
<td>24,000</td>
<td>19</td>
</tr>
</tbody>
</table>
Performance of Public and Private Bus Operators

<table>
<thead>
<tr>
<th>Bus Operator Performance Indicators (ranges)</th>
<th>Public</th>
<th>Private</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average fleet availability (%)</td>
<td>47-85</td>
<td>80-89</td>
</tr>
<tr>
<td>Passengers per bus daily</td>
<td>1200-2200</td>
<td>200-2900</td>
</tr>
<tr>
<td>Passengers per km operated</td>
<td>7.6-10.1</td>
<td>1.2-12.1</td>
</tr>
<tr>
<td>Daily km per bus operated</td>
<td>160-220</td>
<td>170-240</td>
</tr>
<tr>
<td>Staff per bus operated</td>
<td>5.8-13.5</td>
<td>1.0-3.7</td>
</tr>
<tr>
<td>Load factor</td>
<td>0.3-0.6</td>
<td>0.6-0.9</td>
</tr>
<tr>
<td>Profitability (revenue: cost)</td>
<td>0.6-1.2</td>
<td>0.9-3.6</td>
</tr>
</tbody>
</table>
SUCCESSFUL CASE STUDIES IN PUBLIC TRANSPORTATION

**Adaptive Cities**
- Industrialized Countries
  - Portland, Oregon
  - San Diego, California

- Developing Countries
  - Curitiba, Brazil
  - Mexico City

**Adaptive Transit**
- (Tailoring Transit to Serve Cities & Suburbs)
  - Technology-based Solutions (Karlsruhe, Germany)
  - Service Innovations (Adelaide, Australia)
  - Small Vehicle & Private Services
Portland, A Transit Metropolis

Favorable Factors

- Metropolis Governance
- Farsighted Comprehensive Plan
- Prosperous & Growing CBD
- Urban Growth Boundaries
- Parking Policies
- Proactive Station Planning Process

MAX (Metropolitan Area Extension)

- Density Considerations
- Public Policy & Market Needs
Issues and Guiding Principles in Urban Transit Planning

Three underlying objectives:

1. Plan to serve requirement of a metro region involved in globalization processes vital to economic sustainability

2. Plan Framework must aim at equitable access to all including poor (to overcome public policy regimes typically favoring private motor transport).

3. Plan must promote environmental quality and safety.
General Principles and Guidelines

1. Mode Complementarity Principle
2. Innovations in Public Transport Mode
3. Economic and Financial Sustainability
4. Land Development and Land Use Guidance
5. Improving Personal Safety
6. Environmental Sustainability
7. Design of a Governance Structure (Institutional Capacity)
Mode Complementarity Principle

Different Transit Modes Vary in:

• cost
• speed
• seating capacity
• flexibility
• other performance characteristics
• broad ‘regimes’ where mode has advantages over others
View an urban passenger trip as an 'intermodal' trip coordinating modes seamlessly from point A to point B

A functional combination of 'heavy', 'medium' and 'light' modes

This will reduce the fragmentation of metro population into different locations with different incomes and access potentials
Innovations in Public Transport Modes

A core mode of a multi tier metro hierarchical network of transit Modes which (a) provides accessibility services to entire metro Region and (b) is crucial in restraining the use of a private car.

Choices:

1. Underground transport or elevated system
   US$ 100 million/km

2. Busway Systems with a network of feeder buses, special loading platforms, business centers
   US$ 1-3 million/km
   (up to 25,000 passengers/hr/direction. Curitiba, Bogota, São Paulo)
Economic and Financial Sustainability

Key Issues:

Bus or Paratransit (charette) Productivity

Cost Recovery and Fare System

Financing Incentives

Externality Changes (congestion, pollution, etc.)

Demand Management
Bus Productivity a Function of:

- Passenger - km traversed/day
- Salary Levels
- Employees/bus
- 5 in private Brazilian buses, 11.5 in Mumbai (India) & 28 in Accra (Ghana)
- Fare setting & Income Levels
- Pricing
- Externality