Chapter 8
More on Transportation

Remember Overview of Chapter 8
- Transportation
- Power and Energy
  • Batteries, flywheels, hybrids, hydrogen, alcohol
- Traffic safety
- The Automobile
- Mass Transportation

iClicker Question
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)

iClicker Question
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 x d = (1000 N) x (50 m) = 50,000 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

Not Far Away...

Travel times in the USA, 1930

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.
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

Early Motorcycle, 1885

1883 Stationary Gas Engine
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
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.”
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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

[Graph showing urban population growth in Industrial and Developing regions from 1950 to 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>
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</thead>
<tbody>
<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>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 Paulo</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

Road Supply as a Percentage of Urbanized Areas

<table>
<thead>
<tr>
<th>City</th>
<th>Road Space (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing Countries</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>Developed Countries</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>
<th>M&amp;W</th>
<th>Cars</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>14</td>
<td>410</td>
<td>0</td>
<td>20</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>US</td>
<td>24780</td>
<td>740</td>
<td>2</td>
<td>80</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Germany</td>
<td>23800</td>
<td>570</td>
<td>9</td>
<td>89</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>France</td>
<td>25620</td>
<td>520</td>
<td>10</td>
<td>87</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>UK</td>
<td>18340</td>
<td>610</td>
<td>3</td>
<td>86</td>
<td>100</td>
<td>100</td>
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<tr>
<td>Australia</td>
<td>60000</td>
<td>21000</td>
<td>3</td>
<td>76</td>
<td>100</td>
<td>100</td>
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<tr>
<td>S. Korea</td>
<td>82200</td>
<td>20600</td>
<td>24</td>
<td>57</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Brazil</td>
<td>44000</td>
<td>19000</td>
<td>10</td>
<td>82</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Malaysia</td>
<td>3140</td>
<td>2400</td>
<td>56</td>
<td>90</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Thailand</td>
<td>2140</td>
<td>1900</td>
<td>66</td>
<td>16</td>
<td>82</td>
<td>100</td>
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<tr>
<td>The Philippines</td>
<td>950</td>
<td>3200</td>
<td>26</td>
<td>25</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Indonesia</td>
<td>810</td>
<td>5800</td>
<td>58</td>
<td>16</td>
<td>84</td>
<td>100</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>800</td>
<td>6000</td>
<td>60</td>
<td>13</td>
<td>73</td>
<td>100</td>
</tr>
<tr>
<td>China</td>
<td>510</td>
<td>2100</td>
<td>21</td>
<td>24</td>
<td>64</td>
<td>100</td>
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<tr>
<td>India</td>
<td>320</td>
<td>3000</td>
<td>30</td>
<td>14</td>
<td>81</td>
<td>100</td>
</tr>
<tr>
<td>Vietnam</td>
<td>210</td>
<td>2700</td>
<td>27</td>
<td>9</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

**Trip Purpose, Selected Cities**

<table>
<thead>
<tr>
<th>City (Country)</th>
<th>Work</th>
<th>School</th>
<th>Work and School</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algiers (Algeria)</td>
<td>25</td>
<td>50</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>Bangkok (Thailand)</td>
<td>34</td>
<td>18</td>
<td>52</td>
<td>48</td>
</tr>
<tr>
<td>Kolkata (India)</td>
<td>44</td>
<td>29</td>
<td>73</td>
<td>28</td>
</tr>
<tr>
<td>Delhi (India)</td>
<td>46</td>
<td>3</td>
<td>89</td>
<td>1</td>
</tr>
<tr>
<td>Hanoi (Vietnam)</td>
<td>45</td>
<td>19</td>
<td>64</td>
<td>36</td>
</tr>
<tr>
<td>Jakarta (Indonesia)</td>
<td>39</td>
<td>20</td>
<td>59</td>
<td>41</td>
</tr>
<tr>
<td>Santiago (Chile)</td>
<td>36</td>
<td>32</td>
<td>68</td>
<td>32</td>
</tr>
<tr>
<td>São Paulo (Brazil)</td>
<td>41</td>
<td>34</td>
<td>74</td>
<td>25</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>

¹Illegal paratransit
²Individual use only

**Car and Bus Travel Times**

<table>
<thead>
<tr>
<th>City (Country)</th>
<th>Travel Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algiers (Algeria), 1990</td>
<td>56</td>
</tr>
<tr>
<td>Caracas (Venezuela), 1982</td>
<td>54</td>
</tr>
<tr>
<td>Mexico City (Mexico), 1994</td>
<td>50</td>
</tr>
<tr>
<td>São Paulo (Brazil), 1997</td>
<td>56</td>
</tr>
</tbody>
</table>

(¹) Door-to-door travel time, average for all trips
### Traffic Fatalities and Rates, Selected Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Fatalities/10,000 veh</th>
<th>Fatalities/100,000 pop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US, 1995</td>
<td>41,798</td>
<td>31</td>
<td>16</td>
</tr>
<tr>
<td>France, 1984</td>
<td>11,685</td>
<td>6</td>
<td>23</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>15</td>
</tr>
<tr>
<td>Developing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>India, 1996</td>
<td>69,800</td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td>China, 1994</td>
<td>66,322</td>
<td>82</td>
<td>17</td>
</tr>
<tr>
<td>Brazil, 1995</td>
<td>57,886</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>S. Korea, 1995</td>
<td>45,523</td>
<td>12</td>
<td>23</td>
</tr>
<tr>
<td>S. Africa, 1992</td>
<td>10,182</td>
<td>18</td>
<td>32</td>
</tr>
<tr>
<td>Nigeria, 1980</td>
<td>5,936</td>
<td>141</td>
<td>13</td>
</tr>
<tr>
<td>Thailand, 1992</td>
<td>3,184</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Poland, 1992</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>2,873</td>
<td>91</td>
<td>54</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 UN</td>
<td>20</td>
</tr>
<tr>
<td>Latin America</td>
<td>20</td>
</tr>
<tr>
<td>Africa</td>
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<tr>
<td>Middle East</td>
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<tr>
<td>Asia</td>
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</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. The loss in ridership was of short duration; 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 another modest increase in ridership as a result of growing awareness and support for alternatives to the automobile.
Public Transportation

A. Formal and Informal Bus and Other Services
- Decline of Large Bus Operations
- Fare control, investment declines, poorer service
- Corruption and political control
- Failures: Lagos State Transportation Corporation
  - Public Transit Board
- Para Transit Services

B. Urban Transit Options
- Technology
- Operational Form
- Amenities Levels
- Management Form
- Costs

Characteristics of Selected Light Rail Transit Systems

<table>
<thead>
<tr>
<th>City</th>
<th>Light Rail Type</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>
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</tr>
<tr>
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<td>23.0</td>
<td>0.6</td>
<td>1:00</td>
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<td>26</td>
<td>26</td>
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<tr>
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<td>Part u/g, Part a/g</td>
<td>24.0</td>
<td>1.3</td>
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<tr>
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<tr>
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<tr>
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<tr>
<td>Tunis</td>
<td>At grade</td>
<td>10.0</td>
<td>0.8</td>
<td>1:00</td>
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</table>

Performance of Public and Private Bus Operators

<table>
<thead>
<tr>
<th>Performance Indicator (ranges)</th>
<th>Public</th>
<th>Private</th>
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</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
- 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

Mode Complementarity Principle continued

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/ln/dir. 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