Introduction to Rail Transportation

Chris Barkan - University of Illinois at Urbana-Champaign
How many think rail transport is obsolete in the US?

US rail freight traffic: 1920-2010
Rail is the principal means of economically moving large, heavy freight long distances overland.
Rail uniquely combines speed and energy efficiency
Q: Where is the best rail transportation system in the world?

A: It depends!

Passenger or freight?

Passenger: Probably Japan or one of the European countries

Freight: U.S. (and Canada) are virtually undisputed leaders
North American freight transportation volume by mode

Source: AAR from Eno Foundation for Transportation
So who cares about freight transportation?

Everyone should!
Why is railroad freight transport so important now, and even more so in the future?

- Let's consider the alternatives for inland transport
  - truck, water, air, pipeline, conveyor belt
Truck Pros and Cons

- **Pros:** Speed, reliability, network coverage

- **Cons:** Energy efficiency, safety, land use, pollution, cost, congestion (because of shared use of infrastructure truck transport affects auto safety and congestion as well)

Each rail car = approximately three trucks
• Highway network is comprehensive but increasingly congested at many key nodes
Truck Congestion
Waterways Pros and Cons

- **Pros:** Energy efficiency, low cost, low pollution, safety, capacity
- **Cons:** Speed, limited network
US Waterway Freight Flows
Pipelines and Conveyor Belts

- **Pros**: High volume, continuous transport possible, no vehicles needed, low labor requirements
- **Cons**: Highly constrained types of commodities, limited product flexibility, speed and network
Major (Class 1) Railroads

...and over 500 short line & regional railroads
• Seven large (Class 1) freight railroads
  – CSX & NS in eastern US
  – BNSF & UP in west
  – CN & CP in Canada & central US
  – KCS is a medium-sized railroad in central US

• 500 Short-line and Regional railroads

• Amtrak operates passenger trains throughout the US
  Outside the Northeast Corridor these are primarily on freight railroad trackage

• Commuter rail operations in many large cities
Note the importance of the “gateways” Chicago, St. Louis, Kansas City, Memphis, New Orleans

Gateways are where large amounts of freight are interchanged between western and eastern railroads

NOTE: Alaska and Hawaii are not shown here as they have no railroad networks.

Elements of Railway Engineering

Railroad Network
System operation affects efficiency and service reliability

Traffic Control System
Safe, efficient operation of many trains on same tracks

Line & Terminal Operation
Timely and efficient train operation and use of equipment & personnel

Rail Cars
Design and size affect operating efficiency

Locomotive
Efficient conversion of energy into tractive force to pull train

Brake System
Safe stopping distance affects train spacing and line capacity

Track System
Structure & condition affects speed and maintenance requirements

Wheel/Rail Interface
Complex dynamics affect stability & speed
Typical modern freight equipment

• Modern freight locomotive (*GE DashC44CW*)
  4,400 horsepower, 392,000 lbs = 196 tons

• Typical freight cars

Freight cars of two capacities are most common today:

- 263,000 lbs GRL = 131.5 tons  
  “100 ton” or 263K

- 286,000 lbs GRL = 143.0 tons  
  “110-ton” or 286K

Empty: ca. 60,000 lbs = 30 tons each (but varies with size of car)
Basics of freight railcar weight and capacity

- The nominal capacity of a typical, 4-axle railcar today is 110 tons (formerly was 100 ton)
- Maximum Gross Rail Load (GRL) of a 110 ton, 4-axle railcar is 286,000 lbs. (weight of car + contents or “lading”)
- Nominal capacity = 220,000 lbs. or 110 tons of lading
- Often referred to as a “110 ton” car or a “286K” car

Load or Lading

Nominal Capacity
Approx. 220,000 lbs
= 110 tons

Light weight or “tare” approx. 66,000 lbs = 33 tons

Trucks or "bogies"

Carbody

Gross Rail Load (GRL)
66,000 lbs.
+ 220,000 lbs.
286,000 lbs.

(actual light weight will vary somewhat depending on car size, consequently the weight-carrying capacity will vary inversely, i.e lighter car larger capacity)
## Distribution of freight car capacity
(freight cars in service 2011)

<table>
<thead>
<tr>
<th>Maximum GRL</th>
<th>Nominal Capacity</th>
<th>Number of Cars in Service</th>
<th>Percentage of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>220,000 lbs.</td>
<td>70 ton</td>
<td>178,961</td>
<td>11.9%</td>
</tr>
<tr>
<td>263,000 lbs.</td>
<td>100 ton</td>
<td>595,680</td>
<td>39.2%</td>
</tr>
<tr>
<td>286,000† lbs.</td>
<td>110 ton</td>
<td>700,896</td>
<td>46.2%</td>
</tr>
<tr>
<td>315,000 lbs.</td>
<td>125 ton</td>
<td>1,653</td>
<td>0.1%</td>
</tr>
<tr>
<td>All Other*</td>
<td></td>
<td>41,459</td>
<td>2.73%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>1,474,800</strong></td>
<td></td>
</tr>
</tbody>
</table>

† Includes 64,284 cars with maximum GRL = 268,000 lbs. (2011 UMLER data)

* Primarily cars of higher capacity with more than 4-axles
Freight train size and tonnage

• Typical freight train is about 100 cars (generally range from 50 to 150 cars)
  ___ cars x ___ tons lading per car = ______ tons of lading

• Railcar Gross Rail Load = _______ lbs. GRL (= ____ tons)
  ______ cars x _______ lbs. = __________ lbs = ______ gross tons

• Plus the weight of two locomotives, about 300,000 lbs each
  = ___ tons each x 2 = ____ tons of locomotives
  ___+ _____ tons in consist = _____ gross tons per train
Freight train size and tonnage

- Typical freight train is about 100 cars (generally range from 50 to 150 cars)
  \[100 \text{ cars} \times 110 \text{ tons lading per car} = 11,000 \text{ tons of lading}\]

- Railcar Gross Rail Load = \textbf{286,000 lbs.} \textbf{GRL} (= \textbf{143} tons)
  \[100 \text{ cars} \times 286,000 \text{ lbs.} = 28,600,000 \text{ lbs} = 14,300 \text{ gross tons}\]

- Plus the weight of two locomotives, about 300,000 lbs each
  \[= 150 \text{ tons each} \times 2 = 300 \text{ tons of locomotives}\]
  \[+ 14,300 \text{ tons in consist} = 14,600 \text{ gross tons per train}\]
Intercity ton-miles is a common metric for measuring freight traffic

- 1 ton-mile = ___ ton of freight moved ___ mile
- Typical railcar weighs about ____ tons and can transport about ___ tons of lading
- So how many ton-miles does one fully loaded freight car generate when it moves one mile?
  _____ revenue ton-miles = weight of lading x miles
  _____ gross ton miles = (weight of lading + railcar) x miles
- How many does an empty car generate?
  _____ revenue ton-miles
  _____ gross ton miles

- One train per day for a year (including two locomotives) = _______ tons x ___ days = __________ tons = ____ million gross tons (MGT)
- One train moving 100 miles equals = _______ tons x ___ miles
  = __________ gross ton-miles (GTM)
Intercity ton-miles is a common metric for measuring freight traffic

- **1 ton-mile** = 1 ton of freight moved 1 mile
- Typical railcar weighs about **33** tons and can transport about **110** tons of lading
- So how many ton-miles does one *fully loaded* freight car generate when it moves one mile?
  
  **110 revenue ton-miles** = weight of lading x miles
  **143 gross ton miles** = (weight of lading + railcar) x miles
- How many does an *empty* car generate?
  
  **0 revenue ton-miles**
  **33 gross ton miles**
- One train per day for a year (including two locomotives) = **14,600** tons x **365** days = **5,329,000** tons = **5.329 million gross tons (MGT)**
- One train moving 100 miles equals = **14,600** tons x **100** miles
  = **1,460,000 gross ton-miles (GTM)**
Types of freight cars

- Flatcar
- Gondola
- Hopper
- Covered Hopper
- Boxcar
- Tank Car
- Auto Rack Car
Distribution of Freight Car Types

- 1.3 million freight cars operating in North America
- Railroads own about 60% of the fleet, but Class 1 railroads own about 30%
- Covered hoppers most common type,
  - used for grain, plastic pellets, and some chemicals
- Tank cars second most common,
  - used for liquid products
  - about half of these are for hazardous materials
- How much are these cars worth?
  - avg. $98,000 each to replace
  - 1.3 million x $98,000
  = $127 BILLION!
  - Imperative that these assets be well utilized
Railroad Traffic Mix: 2011

- Coal is **King**!
  - In terms of tons originated, it is the leading commodity transported by rail, followed by chemicals, farm products & non-metallic minerals
- Notice that revenue is not directly correlated with tons originated ... Why not?
  - Different commodities tend to be shipped different distances *(longer distance more revenue)*
  - Different commodities command different rates *(more valuable commodities can bear higher shipping rates, but tend to require better service too)*
- What are “Misc mixed shipments”?

<table>
<thead>
<tr>
<th>Commodity Group</th>
<th>Tons Originated (000)</th>
<th>% of Total</th>
<th>Gross Revenue (million)</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>815,986</td>
<td>43.3 %</td>
<td>$16,138</td>
<td>24.7 %</td>
</tr>
<tr>
<td>Chemicals &amp; allied prod.</td>
<td>193,661</td>
<td>10.3 %</td>
<td>8,984</td>
<td>13.8 %</td>
</tr>
<tr>
<td>Farm products</td>
<td>156,507</td>
<td>8.3 %</td>
<td>5,556</td>
<td>8.5 %</td>
</tr>
<tr>
<td>Non-metallic minerals</td>
<td>127,790</td>
<td>6.8 %</td>
<td>2,340</td>
<td>3.6 %</td>
</tr>
<tr>
<td>Misc. mixed shipments*</td>
<td>116,556</td>
<td>6.2 %</td>
<td>8,245</td>
<td>12.6 %</td>
</tr>
<tr>
<td>Food &amp; kindred products</td>
<td>107,334</td>
<td>5.7 %</td>
<td>5,133</td>
<td>7.9 %</td>
</tr>
<tr>
<td>Metallic ores</td>
<td>76,035</td>
<td>4.0 %</td>
<td>699</td>
<td>1.1 %</td>
</tr>
<tr>
<td>Metals &amp; products</td>
<td>50,343</td>
<td>2.7 %</td>
<td>2,517</td>
<td>3.9 %</td>
</tr>
<tr>
<td>Petroleum &amp; coke</td>
<td>43,792</td>
<td>2.3 %</td>
<td>2,025</td>
<td>3.1 %</td>
</tr>
<tr>
<td>Waste &amp; scrap materials</td>
<td>42,778</td>
<td>2.3 %</td>
<td>1,294</td>
<td>2.0 %</td>
</tr>
<tr>
<td>Stone, clay &amp; glass prod.</td>
<td>41,801</td>
<td>2.2 %</td>
<td>1,599</td>
<td>2.4 %</td>
</tr>
<tr>
<td>Pulp, paper &amp; allied prod.</td>
<td>31,628</td>
<td>1.7 %</td>
<td>2,090</td>
<td>3.2 %</td>
</tr>
<tr>
<td>Lumber &amp; wood products</td>
<td>25,452</td>
<td>1.3 %</td>
<td>1,370</td>
<td>2.1 %</td>
</tr>
<tr>
<td>Motor vehicles &amp; equip.</td>
<td>23,403</td>
<td>1.2 %</td>
<td>4,046</td>
<td>6.2 %</td>
</tr>
<tr>
<td>All other commodities</td>
<td>32,372</td>
<td>1.7 %</td>
<td>3,221</td>
<td>4.9 %</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,885,437</strong></td>
<td><strong>100.0 %</strong></td>
<td><strong>$65,258</strong></td>
<td><strong>100.0 %</strong></td>
</tr>
</tbody>
</table>

* Miscellaneous mixed shipments (STCC 46) is almost all intermodal traffic. Some intermodal traffic is also included in commodity-specific categories. STCC 46 accounts for about two thirds of intermodal tonnage.
** Gross Revenue is not adjusted for absorption (incentive rebates etc.) or correction.
Intermodal revenues exceeded coal for the first time in 2004

- Intermodal* - $8.8
- Coal - $8.4
- Chemicals - $5.1
- Motor vehicles & parts - $3.7
- Farm products (mainly grain) - $3.2
- Food - $2.9
- Lumber & wood - $1.9
- Pulp & paper - $1.7
- Primary metal products (e.g., steel) - $1.5
- Stone, clay & glass products (e.g., cement) - $1.3
- Nonmetallic minerals (e.g., sand, gravel) - $1.1

- Amounts shown in $billions
- Since 2004, intermodal revenue slipped back into 2nd place, but the long-term trend is clear - intermodal will dominate

(From AAR)
Intermodal Definition

• Intermodal shipment: a freight shipment that moves between origin and destination using two or more modes of transportation

• Two types of intermodalism:
  – Bulk
  – Unitized

• Growth of unitized intermodal shipments has been a spectacular trend in transportation

• Domestic and internationally standardized designs for containers
Intermodal freight

Intermodal transportation by more than one means of conveyance, as by truck, ship and/or rail
Basic types of unitized intermodal equipment & service

- Railroad intermodal transportation is typically described as either:
  - Trailer on flatcar (TOFC)
  - Container on flatcar (COFC)
- Although the early railcars used to transport these were flatcars, intermodal rolling stock has become highly specialized
- “RoadRailer”, is a system in which a container can ride directly on either a highway or railroad wheel assembly, without any railcar required
Intermodal growth has been entirely in containers since the mid-1990s.

Trailer on flatcar (TOFC) traffic peaked in 1994 and has generally declined since then.
Rail movement of intermodal traffic in US

- Rail lines serve as a “land bridge” for Pacific rim goods destined for the east coast and Europe
- All of the west coast ports are important, but the dual ports of Los Angeles and Long Beach (San Pedro Bay) in Southern California are by far the dominant
Alameda Corridor connecting Ports of Los Angeles and Long Beach with U.S. railroad network

Opened April 2002 - on time and on budget
U.S. Rail Network Depends on Chicago

- 25 percent of all U.S. rail traffic “touches” Chicago
- 46 percent of all intermodal units in the U.S. touch Chicago
- 54 percent of intermodal units to/from the ports of Seattle/Tacoma touch Chicago
- 26 percent of intermodal units to/from Los Angeles/Long Beach touch Chicago
- Freight rail trade with Chicago is expected to increase 89% by 2035*
- Passenger, freight and motorist delays are experienced daily on the current system
- The region must improve freight movement and mitigate negative impacts
Chicago terminal network needs extensive infrastructure work to accommodate growing freight and passenger demand

- Current infrastructure insufficient to handle existing traffic efficiently, nevermind the extensive projected growth
  - Track connections
  - Signaling and control
  - Grade crossings
- Extensive shared used by freight, commuter and intercity passenger trains
- Ten different railroads

(From Trains Magazine)
Chicago CREATE Plan

- Creation of 5 new corridors
  - Central
  - Western Avenue
  - Beltway
  - East-West Connector
  - Passenger Express
- New trackage
- New connections
- New signaling
- Grade crossing eliminations
- Multi-year, $1.5 billion project
- Railroads working with city, state and federal governments
CREATE Program – 70 Projects

- 25 road/rail grade separations
- 6 passenger/freight rail grade separations
- Railroad projects to improve rail infrastructure and upgrade technologies
- Viaduct improvement program
- Grade crossing safety enhancements
- Rail operations and visibility improvements
CREATE will also benefit midwest intercity passenger rail
Broad set of safety concerns for railroads

- Safety of passengers, employees, infrastructure, rolling stock, hazardous materials, operations, highway vehicles, pedestrians and communities
SAFETY FIRST! Railroads have fostered a strong safety culture among operating employees for nearly a century

- Dates to the “Safety First” movement of the early decades of the 20th century
- Railroads continuously stress safety in and out of the workplace
- Extensive investment in technology to improve safety and efficiency
- Railroads also have regular, ongoing training schools and programs for operating personnel
- Who are the principal victims of rail incidents?
  - Primarily
    - Trespassers
    - Grade Crossings
  - Also
    - Employees
    - Passengers
    - Other

95% of Rail-Related Fatalities in 2007 Involved Grade Crossing Collisions or Trespassers

- Trespassers 472
- Grade Crossings 337
- Employees on Duty 17
- Passengers 5
- Other 20

Source: FRA
Railroad Employee Safety

• Safety of railroad employees has improved dramatically over the past 30 years
  – Training
  – Operating Rules
  – Technology
• Bureau of Labor Statistics
  – Railroad employee injury rates are lower than most other industries
Railroad Train Accident Rate: 1980 - 2011

- Train accident rate dropped steeply following deregulation, then leveled off, and has begun declining again:
  76% since 1980 and
  34% since 2000
Railroad/Highway Grade Crossing Incident Rate: 1980 - 2011

- Grade crossing collision rate has dropped steadily: 82% since 1980 and 44% since 2000
Railroad Trespasser Fatality Rate: 1980 - 2010

- Trespasser fatality rate has fluctuated over the past 30 years, but is only slightly lower
- Many of these involve intoxication or suicide
Major Railroad Organizations & Regulators

ASSOCIATION OF AMERICAN RAILROADS

RAILINC

Transportation Technology Center, Inc.

RAILWAY SUPPLY INSTITUTE

AREMA

ASLRRRA

FRA

DEPARTMENT OF TRANSPORTATION

UNITED STATES OF AMERICA

SURFACE TRANSPORTATION BOARD

NATIONAL TRANSPORTATION SAFETY BOARD

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