Enhancing Mobility Through Technology in a Congested Urban Environment

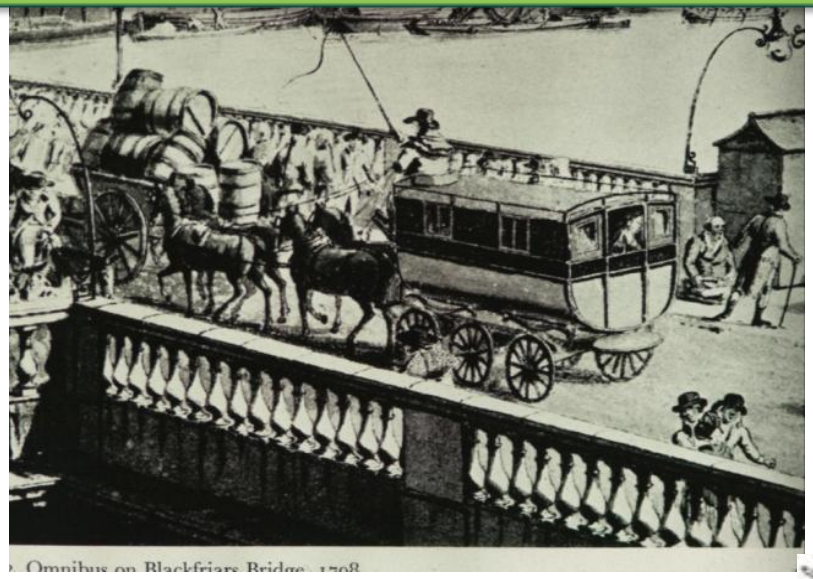
Evolution of Ground Transport Technology: From the Omnibus through Personal Rapid Transit (PRT) to autonomousTaxis (aTaxis)

The Problem: Urban Congestion Snarls Mobility

Also issues about accessibility and equality of access

Over the years technology has evolved…

From:
Omnibus on Blackfriar's Bridge, 1798



Omnibus on Blackfriars Bridge, 1798

To:
Hummers ~2007 (Pre Crisis)

To:
Prius & Tesla 2015 (?????)

To:
GoogleCars ~ 2017+ ???

ORFE

Evolution of the OmniBus

for intra-urban mass transportation

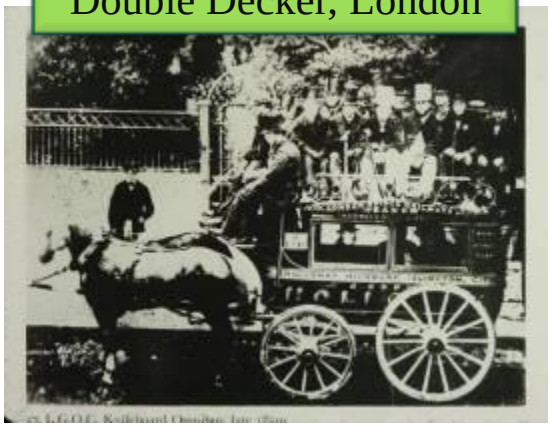
Start: London,1798

Technology Elements:

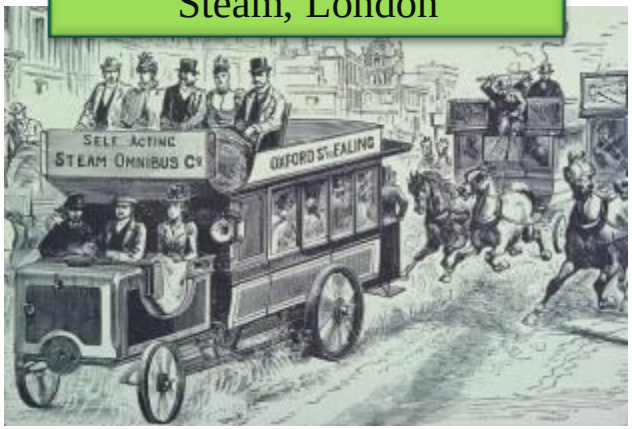
- **Capacity: ~10 Seated Passengers**
- **Propulsion: Horses or Mules**
- **Externalities: Disease and non-operating revenue from pollution**
- **Suspension: Steel Sprung Wooden Wheel with solid axel**
- **Way: "Flat" Pavement (stone, wood, compacted earth)**
- **Headway & Lateral Control: Human**

Geo Enhancement: NYC, 1830

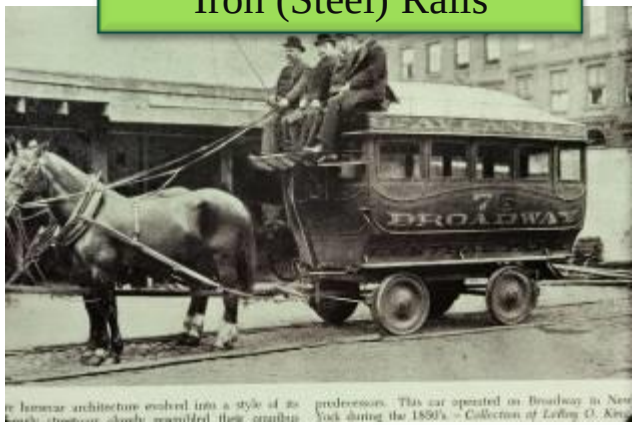
Capacity Enhancement: Double Decker, London



Propulsion Enhancement: Steam, London



Support Enhancement: Iron (Steel) Rails



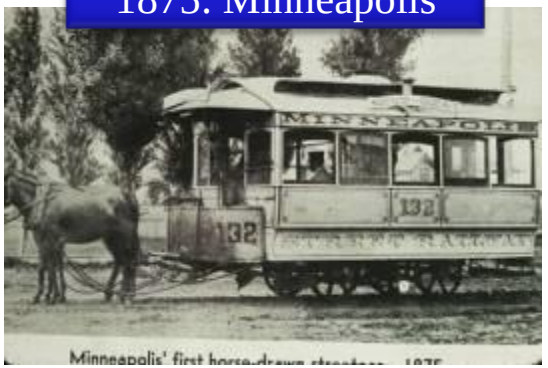
ORFE

Growth of Horse-Drawn Street Railway Technology

1850: NYC

1860: London

1875: Minneapolis



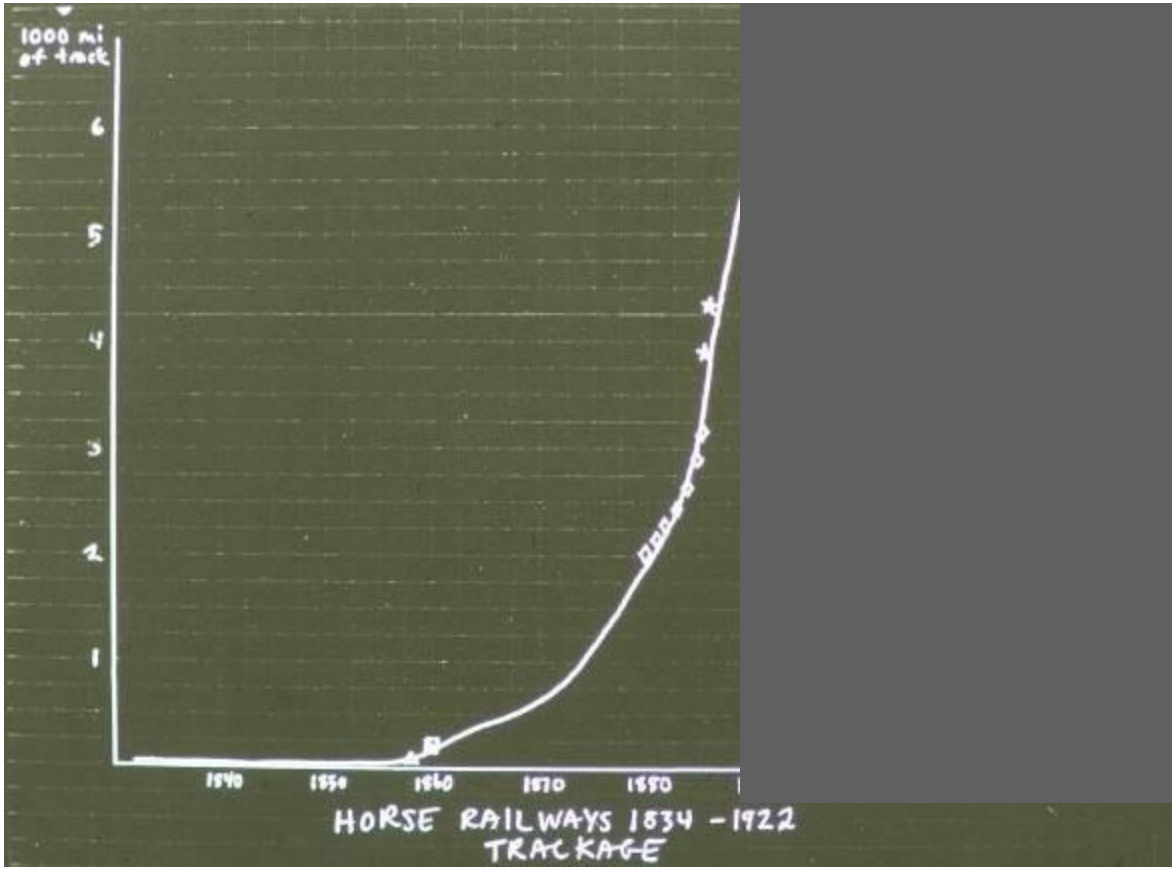
Minneapolis' first horse-drawn streetcar ... 1875

1890: Broadway NYC

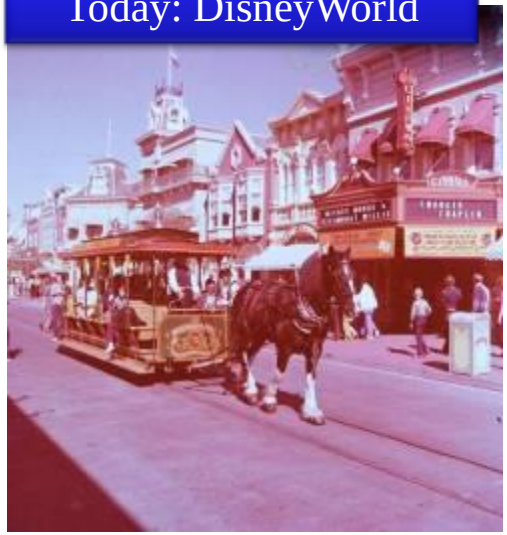
1908: Washington , GA

Discriminating travelers on New York's Third Avenue Railroad rode aboard this richly furnished drawing-room car constructed for the horsecar line in 1871 by the Pullman Palace Car Company. The car made four round trips daily except Sunday. – *Courtesy of Pullman Company and Railroad Magazine.*

Evolution of Horse-Drawn Street Railway Technology



Today: DisneyWorld



Princeton University

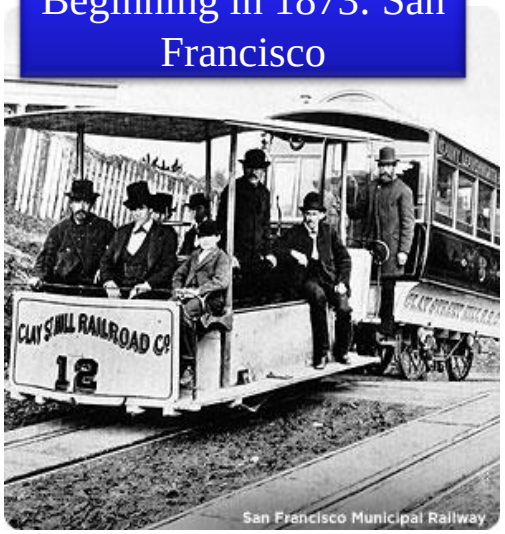
Orf 467 – Transportation Systems Analysis

Fall 2014/15

Growth of Cable Street Railway Technology

1880: Washington, DC

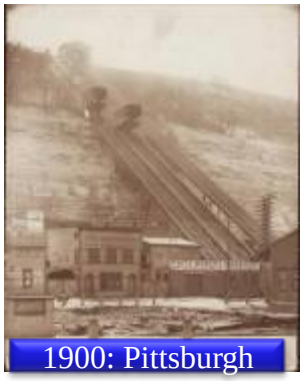
Beginning in 1873: San Francisco



1882: Portland, OR

1874: Hoboken

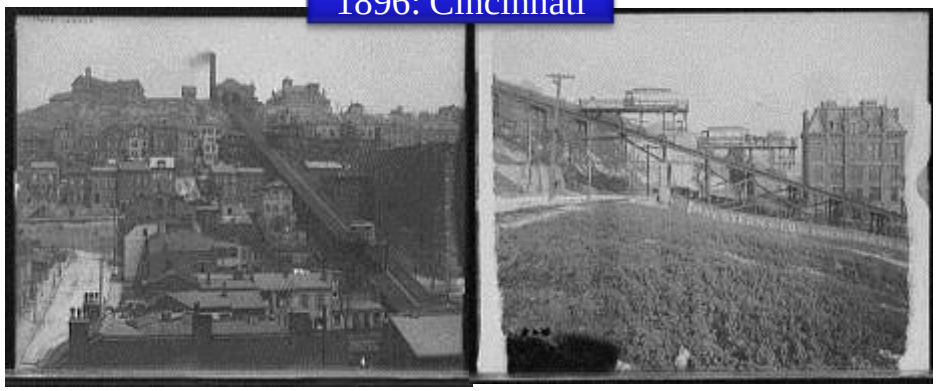
1900: Pittsburgh



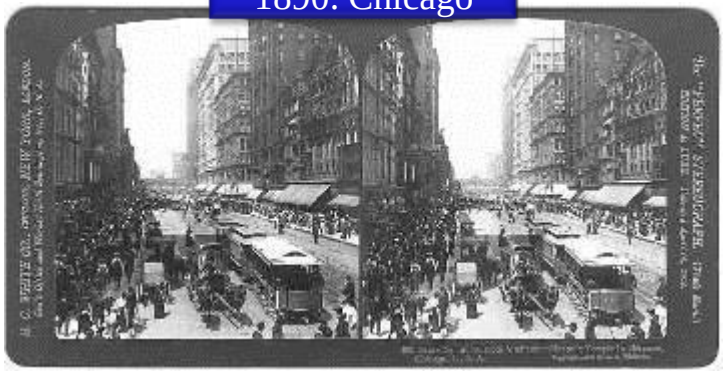
1880: Los Angeles

1890: Kansas City

1896: Cincinnati

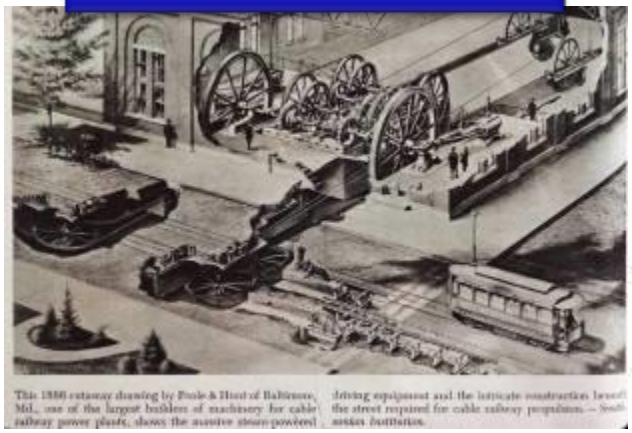


1890: Chicago



Elements of Cable Street Railway Technology

1886: Steam Power Plant



This 1886 cutaway drawing by Poole & Hunt of Baltimore, Md., one of the largest builders of machinery for cable railway power plants, shows the massive steam-powered driving equipment and the intricate construction beneath the street required for cable railway propulsion. – Smithsonian Institution.

Hoboken Grip

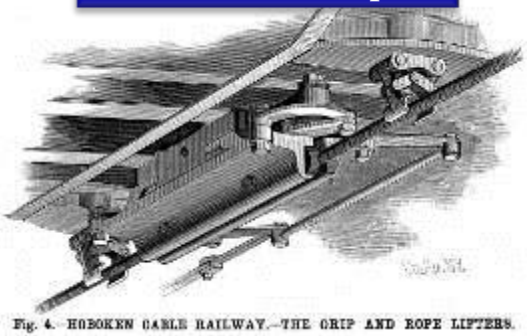
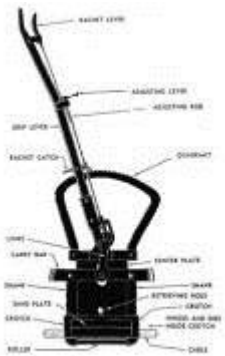
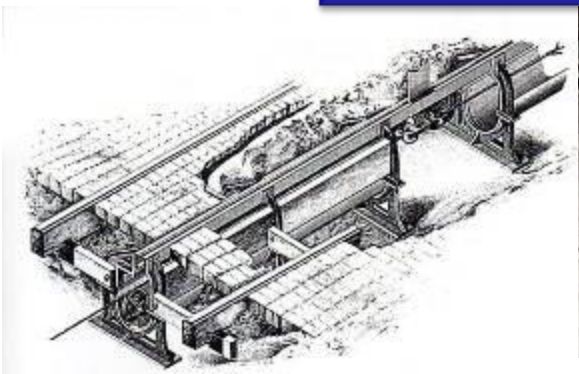


Fig. 4.—HOBOKEN CABLE RAILWAY.—THE GRIP AND ROPE LIFTERS.



GRIP DIAGRAM

Under the street



Elements of Cable Street Railway Technology

San Francisco

Interior

Gripper

Let Go xing

Stuck

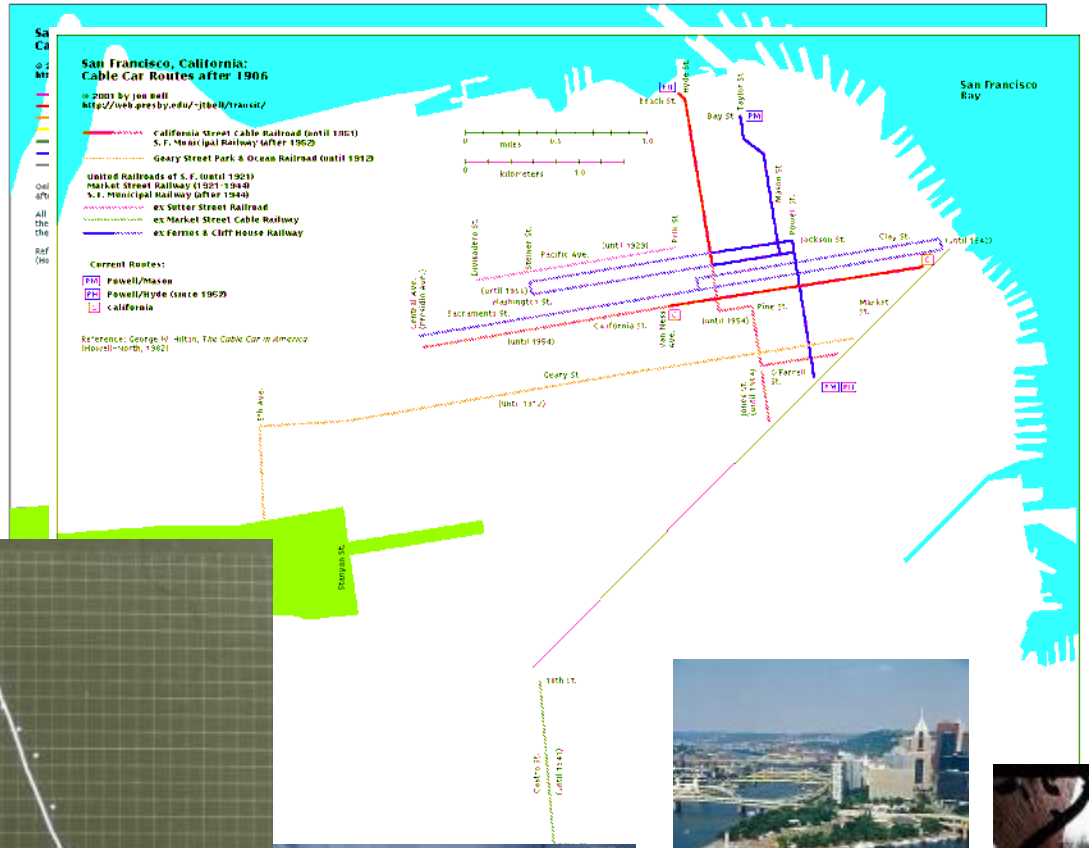
Push

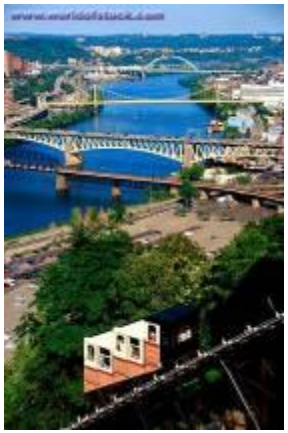
Cable Car Bell Ringing Contest

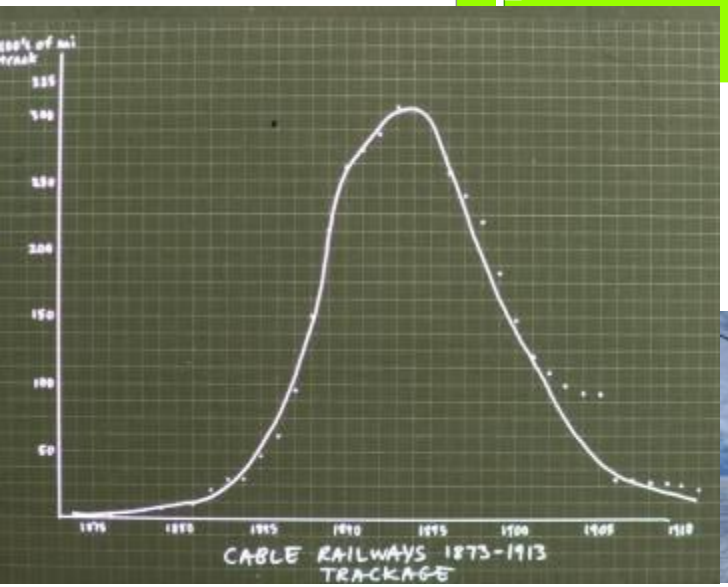
http://cable-car-guy.com/html/ccmain.html

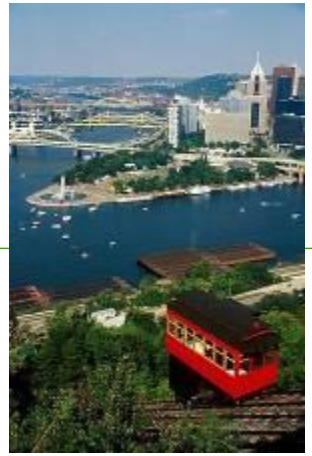
Evolution of Cable Street Railway Technology

Beginning 1873: SF







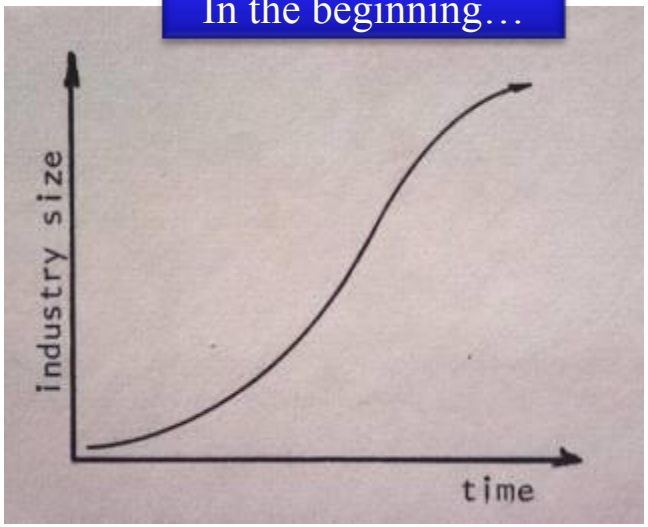


[Cable Car Bell Ringing Contest] [http://cable-car-guy.com/html/ccmain.html] [More images, incline RR]

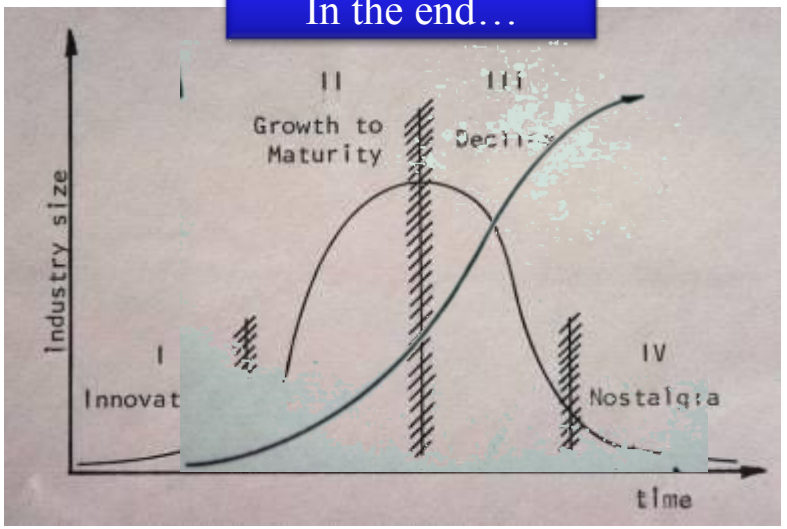
ORFE

Birth-Death Process of Transport Technology

In the beginning…



In the end…



"… [I]n capitalist reality…, it is not [price] competition which counts but the competition from the new commodity, the new technology…- competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives." Joseph A Shumpeter (1883-1950)

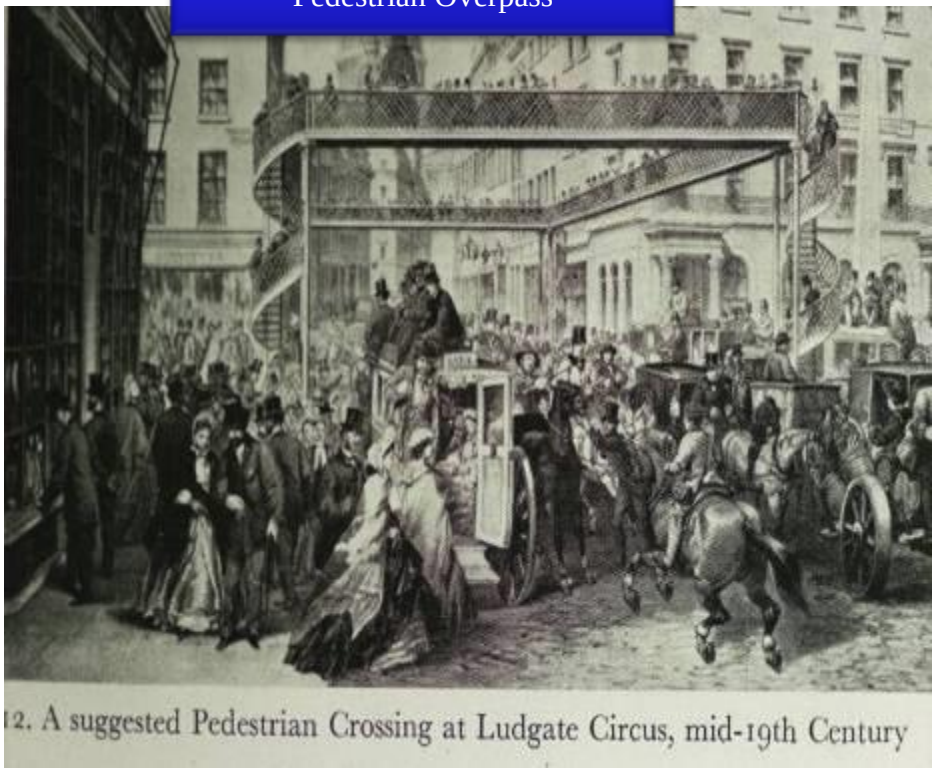
2nd half of 19th Century is a period of industrialization and rapid growth of cities

- In response, cities can occupy the same area at a higher density, implying higher congestion, or

- Expand over a larger area, requiring better transportation technology.

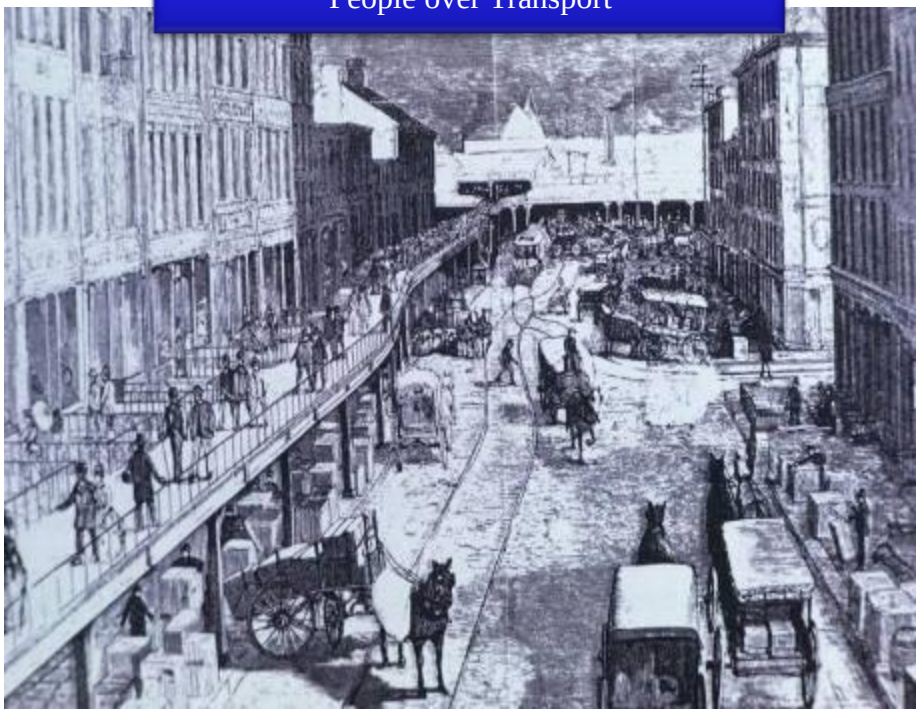
Mid-Late 19th C ways to address congestion through segregation of modes

Pedestrian Overpass



12. A suggested Pedestrian Crossing at Ludgate Circus, mid-19th Century

People over Transport



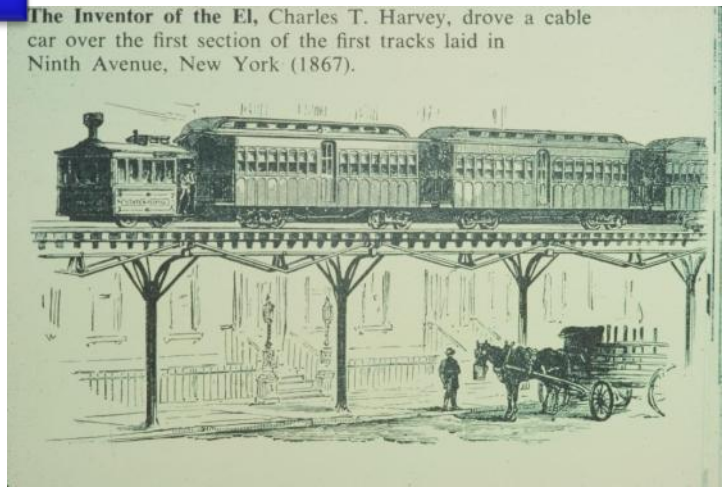
Segregation of Modes

Transport over People

London

NYC

STONE VIADUCT ELEVATED RAILROAD. PROPOSED IN 1833 AS A SOLUTION OF NEW YORK'S RAPID TRANSIT PROBLEM



The Inventor of the El, Charles T. Harvey, drove a cable car over the first section of the first tracks laid in Ninth Avenue, New York (1867).

DESIGN PATENTED BY DR. R. H. GILBERT JUNE 30, 1874, FOR AN ELEVATED STRUCTURE TO BE OPERATED WITH STEAM LOCOMOTIVES

Showing proposed dispatch tubes, telegraph lines, conduits to catch water or drippings, and curved guards to prevent objects falling from the structure to the street. View at Broadway and Vesey Street, looking south, St. Paul's at the right.

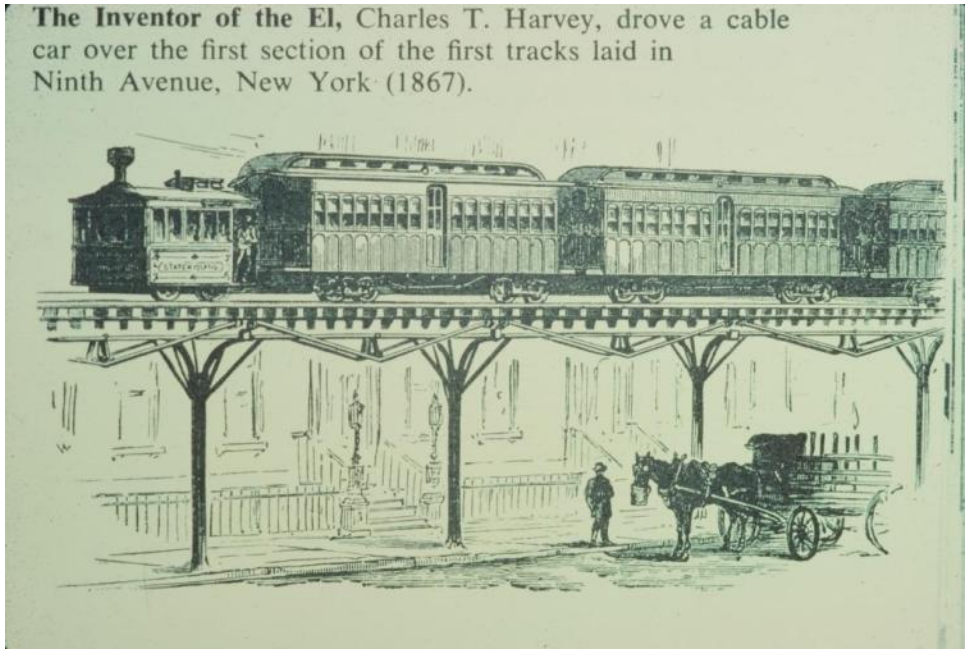
PLAN OF AN ELEVATED STREET RAILROAD (STEAM OPERATION) PROPOSED BY GENERAL FRANZ SIGEL, 1872

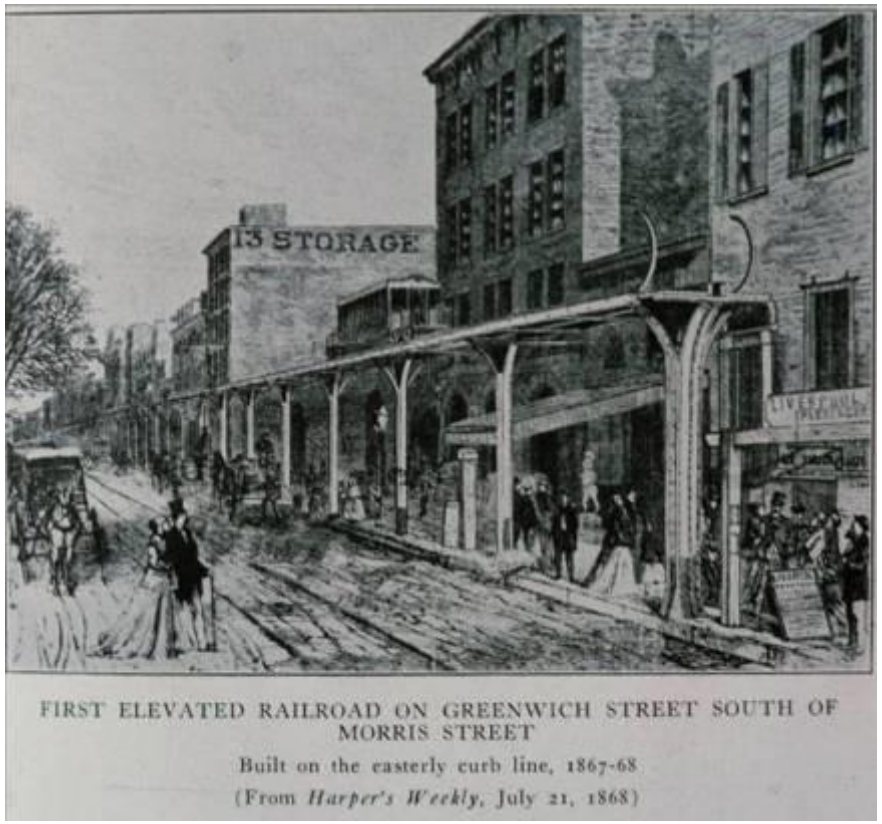
PROPOSED ELEVATED RAILROAD FOR BROADWAY PATENTED BY RICHARD P. MORGAN, 1869

Showing Broadway and Ann Street, looking south, with St. Paul's Church at the right foreground.

Segregation of Modes

Building the First Elevated RR in NYC
Commenced Service, 7/2/1867 (cable powered, converted to steam 2/14/1883)





Segregation of Modes

Building the First Elevated RR in NYC

GREENWICH STREET LOOKING SOUTHEAST FROM DEY STREET, 1868-69

Showing the elevated structure on the east curb line of Greenwich Street, built in 1868-69, cable used for train operation, showing the first south station at Dey and Greenwich Streets in course of construction.

GREENWICH STREET, LOOKING SOUTHEAST FROM THE CORNER OF FULTON STREET, 1869

Showing the first elevated railroad, erected 1868-69 on the easterly curb line of Greenwich Street in front of the Ocean National Bank, and operated by cable.

Segregation of Modes

Building Elevated RR in NYC

NINTH AVENUE, NORTH FROM GANSEVOORT STREET, MAY, 1876

owing the elevated structure extending north from the east curb of Greenwich eet to Little West 12th Street, thence on the west curb of Ninth Avenue. The nsevoort Street turnout is shown extending south on the west side of the extreme ith end of Ninth Avenue. The structures were built 1868-69; the first train was run February 14, 1870.

NINTH AVENUE, NORTH FROM 13TH STREET, MAY, 1876

Showing the elevated structure built on the west curb line, 1868-69; the 14th Street

Segregation of Modes

Building Elevated RR in NYC

NINTH AVENUE, NORTH FROM GANSEVOORT STREET, MAY, 1876

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NINTH AVENUE, NORTH FROM 13TH STREET, MAY, 1876

Showing the elevated structure built on the west curb line, 1868-69; the 14th Street

Segregation of Modes

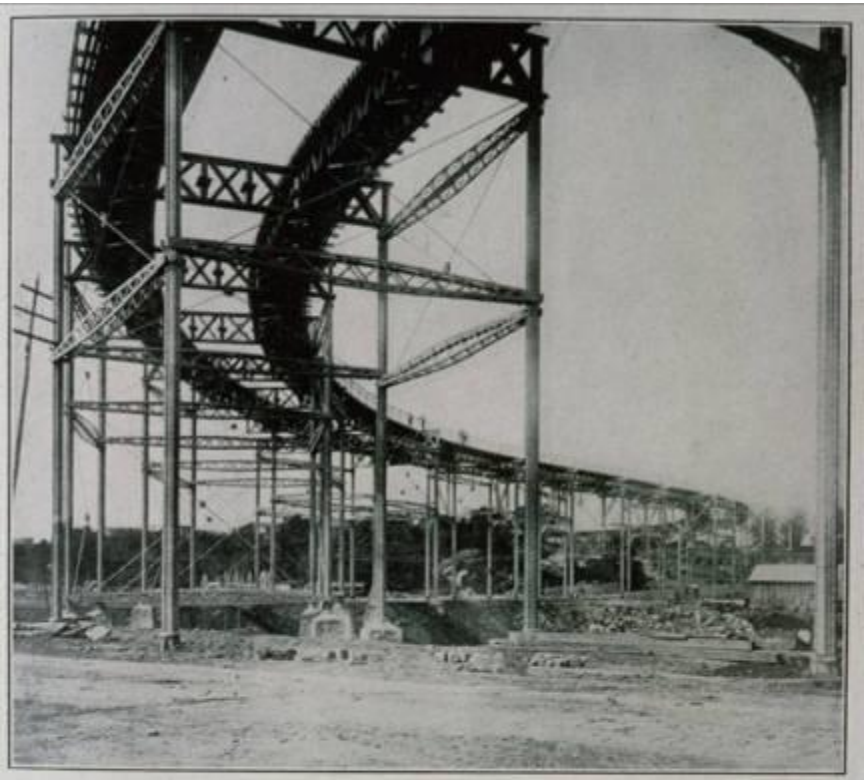
Building Elevated RR in NYC

NINTH AVENUE, NORTH FROM 43RD STREET, MAY, 1876
Showing the original elevated structures built in 1875-76 on the west curb line; and the new "L" on the roadway, east of the surface car tracks, nearing completion.

TWO-TRACK JOINT STRUCTURE OF THE NEW YORK ELEVATED RAILROAD (NINTH AVENUE LINE) AND THE METROPOLITAN ELEVATED RAILWAY (SIXTH AVENUE LINE) ON NINTH AVENUE (COLUMBUS AVENUE), LOOKING SOUTH FROM WEST 83RD STREET, IN 1878-79
This two-track structure was built from 53rd to 83rd Streets, on Ninth Avenue.

Segregation of Modes

Building Elevated RR in NYC



METROPOLITAN ELEVATED RAILWAY STRUCTURE ON 110TH STREET (NOW CATHEDRAL PARKWAY), LOOKING SOUTHWEST FROM EIGHTH AVENUE, 1878-79

In the distance, at the left, Lion Park is shown, located at 109th Street, east side of Ninth Avenue.

STRUCTURE OF THE METROPOLITAN ELEVATED RAILWAY COMPANY (SIXTH AVENUE LINE) BEING ERECTED ON NINTH AVENUE (COLUMBUS AVENUE) IN 1878-79

One of the highest spots of the elevated structures. Looking southwest from 96th Street. Remains of the old Croton Aqueduct (built in 1842) visible at the extreme right.

Segregation of Modes

Building Elevated RR in NYC

6th Ave Line Station, 1878

STATION OF THE METROPOLITAN ELEVATED RAILWAY COMPANY (SIXTH AVENUE LINE) AT SIXTH AVENUE AND 53rd STREET
The station was opened June 6, 1878
Showing the old Standard Theatre, on the west side of Sixth Avenue, between 52nd and 53rd Streets, in the block now occupied by Gimbel's department store.

6th Ave Line, 1945

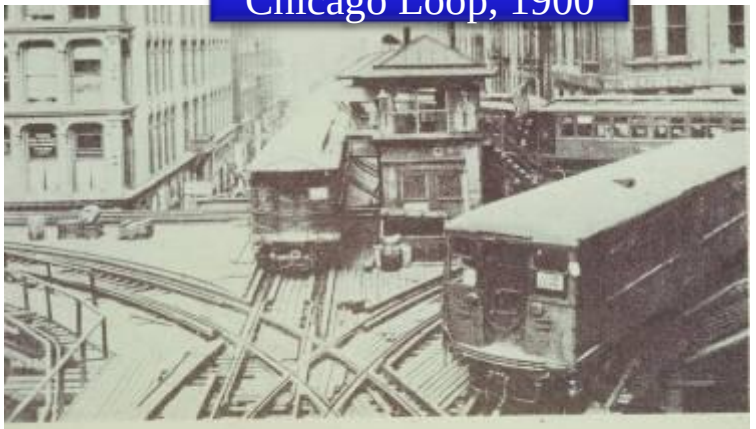
112. New York City's Sixth Avenue elevated and the crowded street below, ca. 1945. *208-EX-236-12*

2nd Ave Line, 1900

Following the successful testing of a Sprague system multiple-unit train on the Second Avenue El in 1900, the New York elevated roads decided to electrify. Two years and 18 million dollars later, electrification was complete. Here multiple-unit trains of the Third Avenue line rumbled along above Bowery trolley traffic. – *Library of Congress*

3rd Ave Line

Chicago Loop, 1900

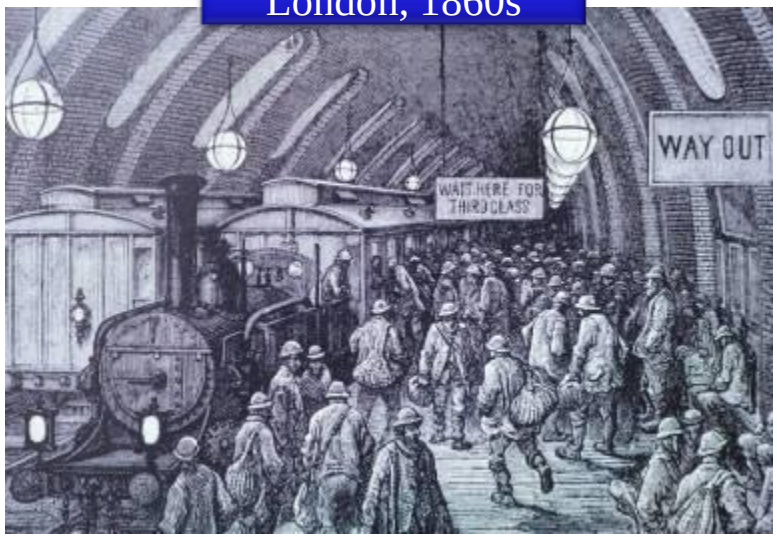


A busy intersection of elevated-railway lines in Chicago's Loop district.

Segregation of Modes

Going Underground: Transport Under People

London, 1860s



Baker St. Station, London Metropolitan, commenced service 1/10/1863

Cut & cover, Paddington,1866

The Metropolitan under Construction at Praed Street, Paddington, about 1866

NYC Park Ave, 1880

Boston, 1st US, 1904

Electric Traction

Princeton University

Orf 467 – Transportation Systems Analysis

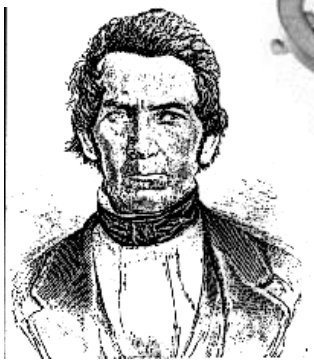
Fall 2014/15

Innovation of Electric Traction

The Innovators

Thomas Davenport (1802-1851)

an American blacksmith and inventor who invented the first DC electrical motor in 1834 and made a small model of electrical railway in 1835. He patented a device for "Improvements in propelling machinery by magnetism and electromagnetism" in 1837 (his electric railway).



Davenport's model of an electric "train." The circular track is 4 feet in diameter. Power was supplied from a stationary battery to the moving electric locomotive, using the rails as conductors

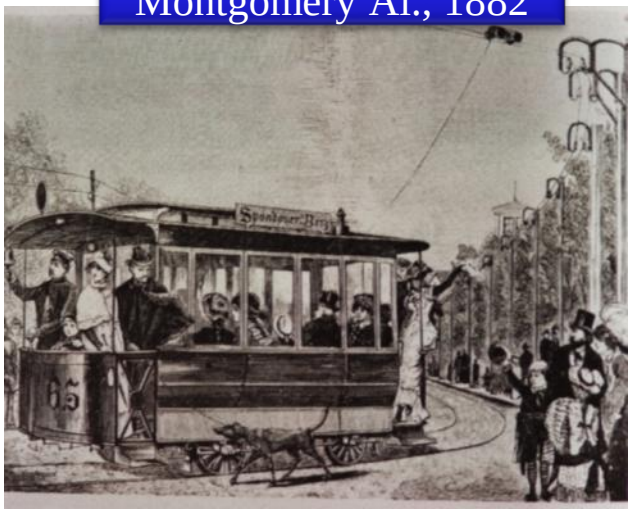
for the electricity

Berlin, 1879

Werner Von Siemens 1816-1892

Kurfurstendamm St., 1879

Montgomery Al., 1882

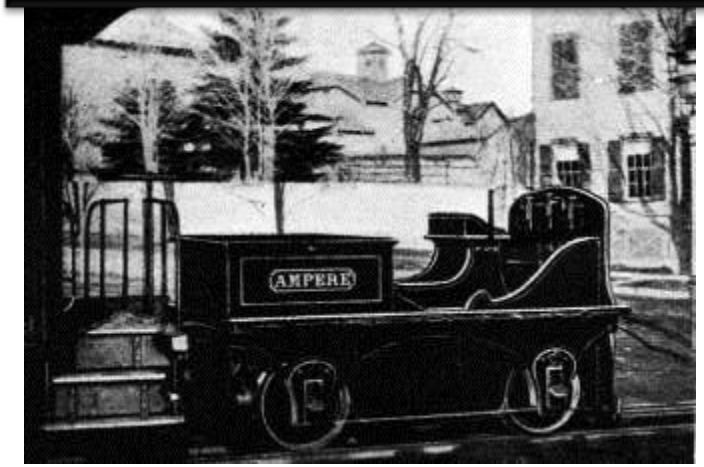


ORFE

Innovation of Electric Traction

The Innovators

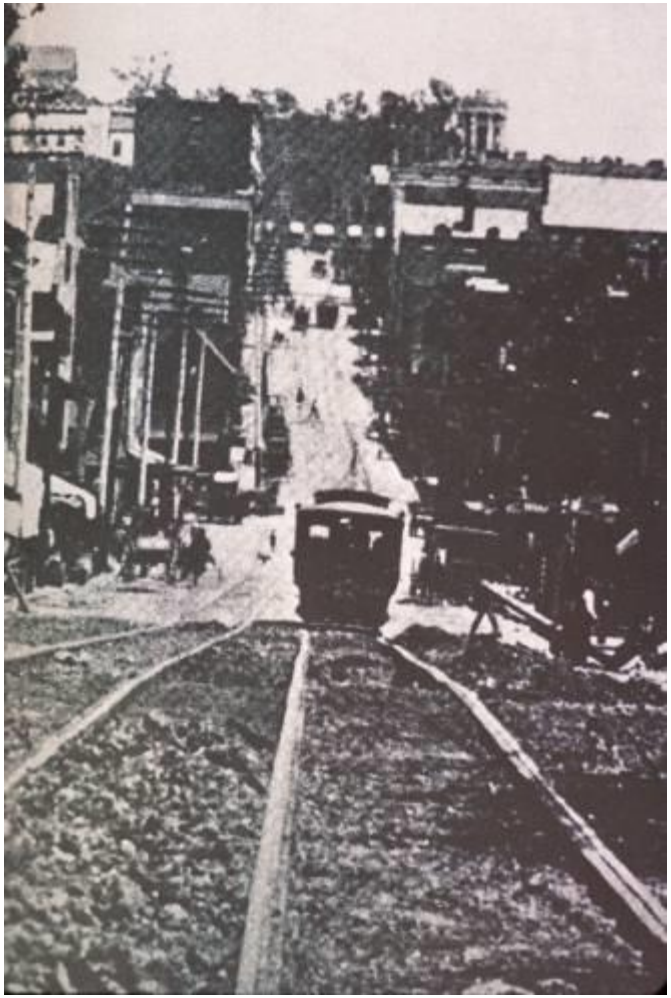
Leo Daft (1843-1922) Baltimore 1885
Uses 3rd rail



Charles Van Depoele 1846-1892
Chicago Demonstration 1883, overhead wiresaa

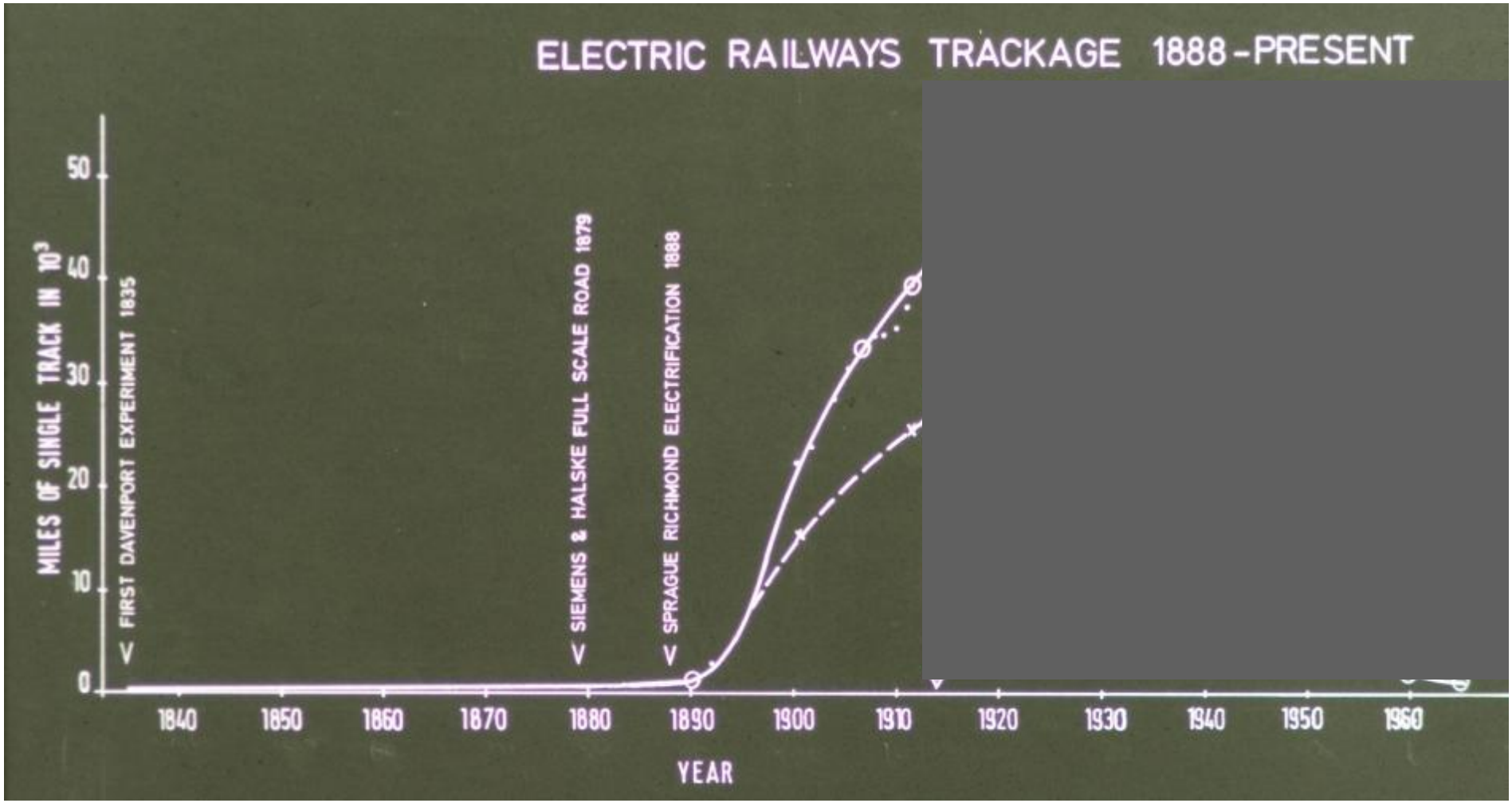
Innovation of Electric Traction

1st Really Successful System Richmond, VA, 1888



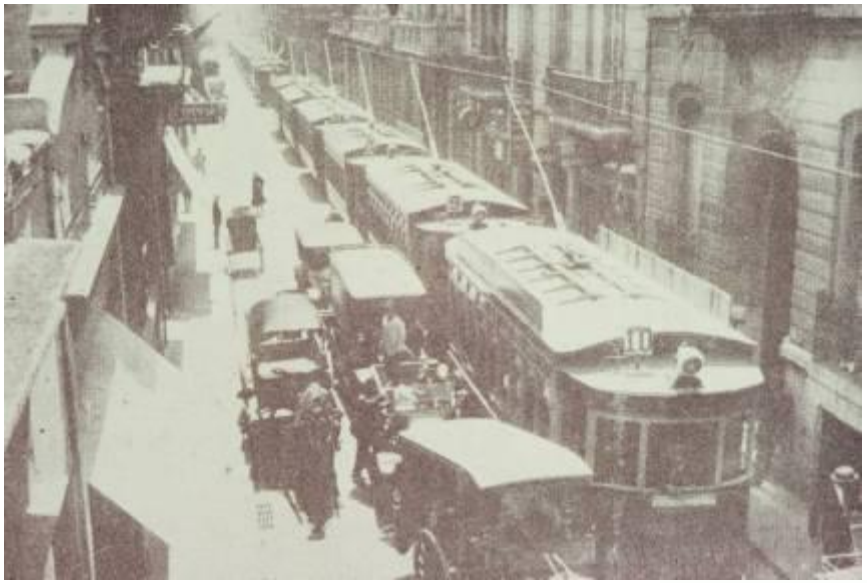
Frank J Sprague 1857-1934

Growth to Maturity of Electric Traction



Growth to Maturity of Electric Traction

Newark, NJ, 900



Princeton University

Growth to Maturity of Electric Traction

Orf 467 – Transportation Systems Analysis

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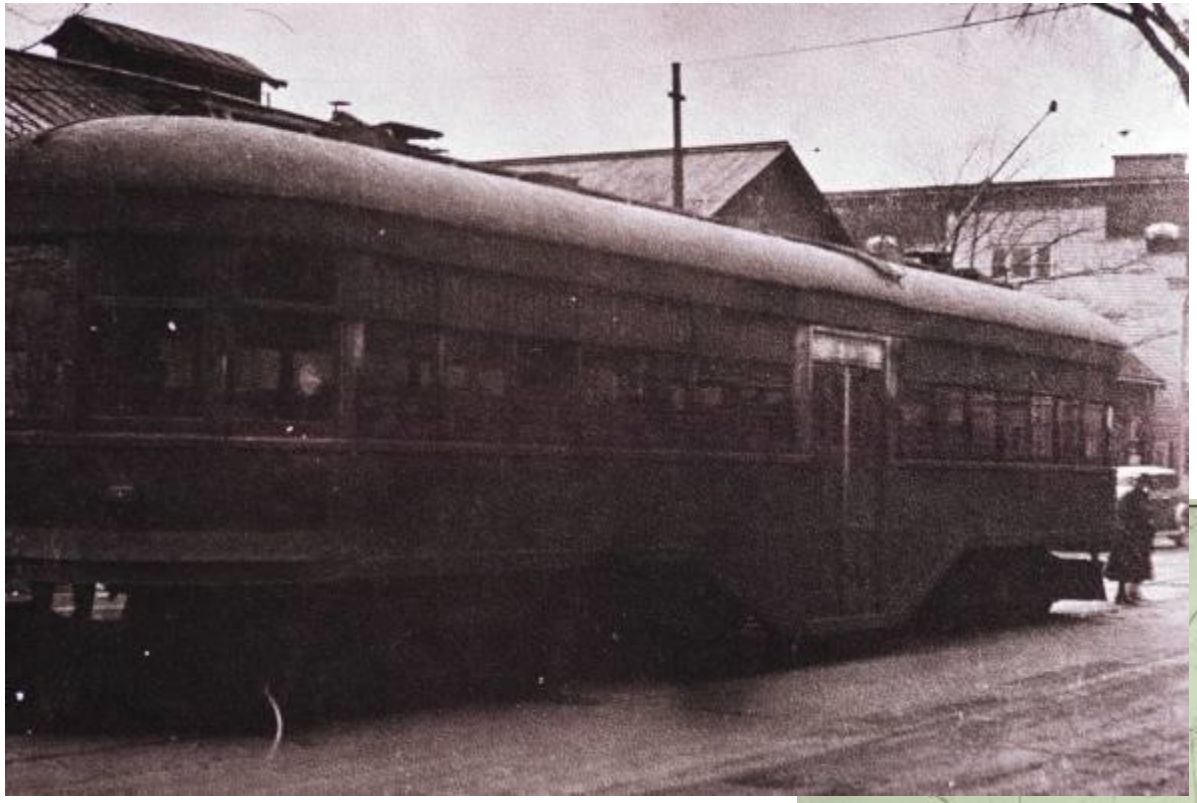
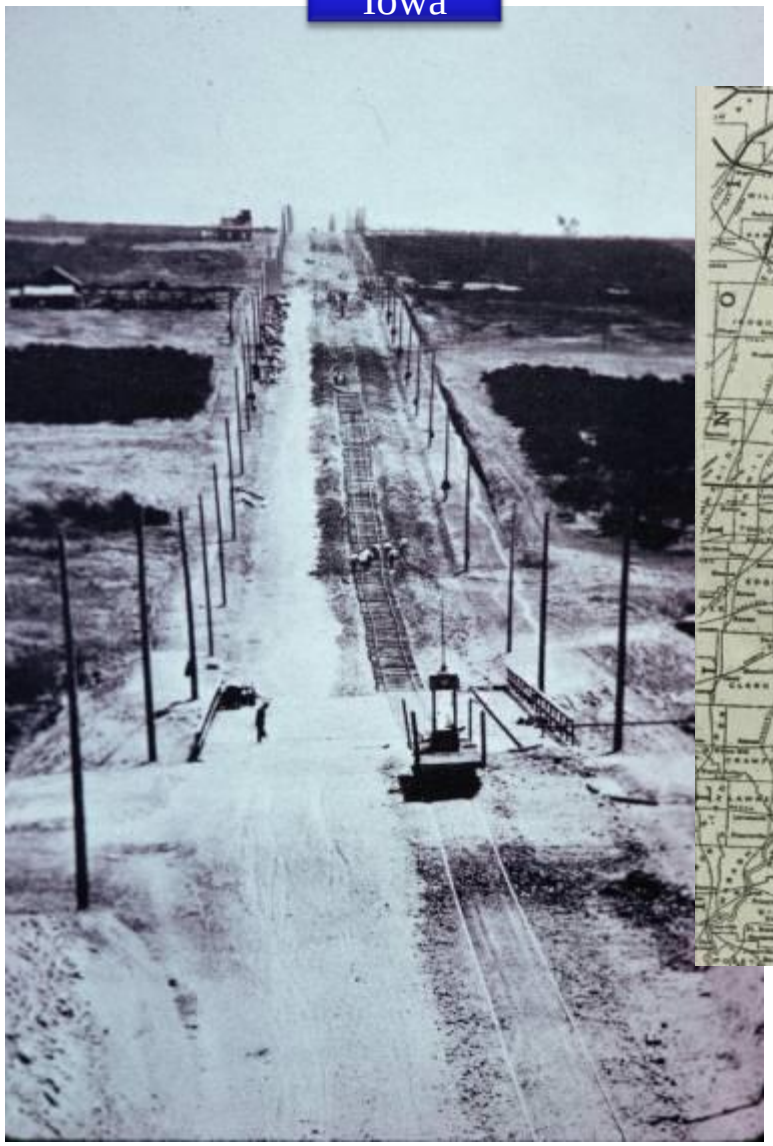


Witherspoon St.
@ Gate to Nassau Hall
Princeton, NJ, 1930

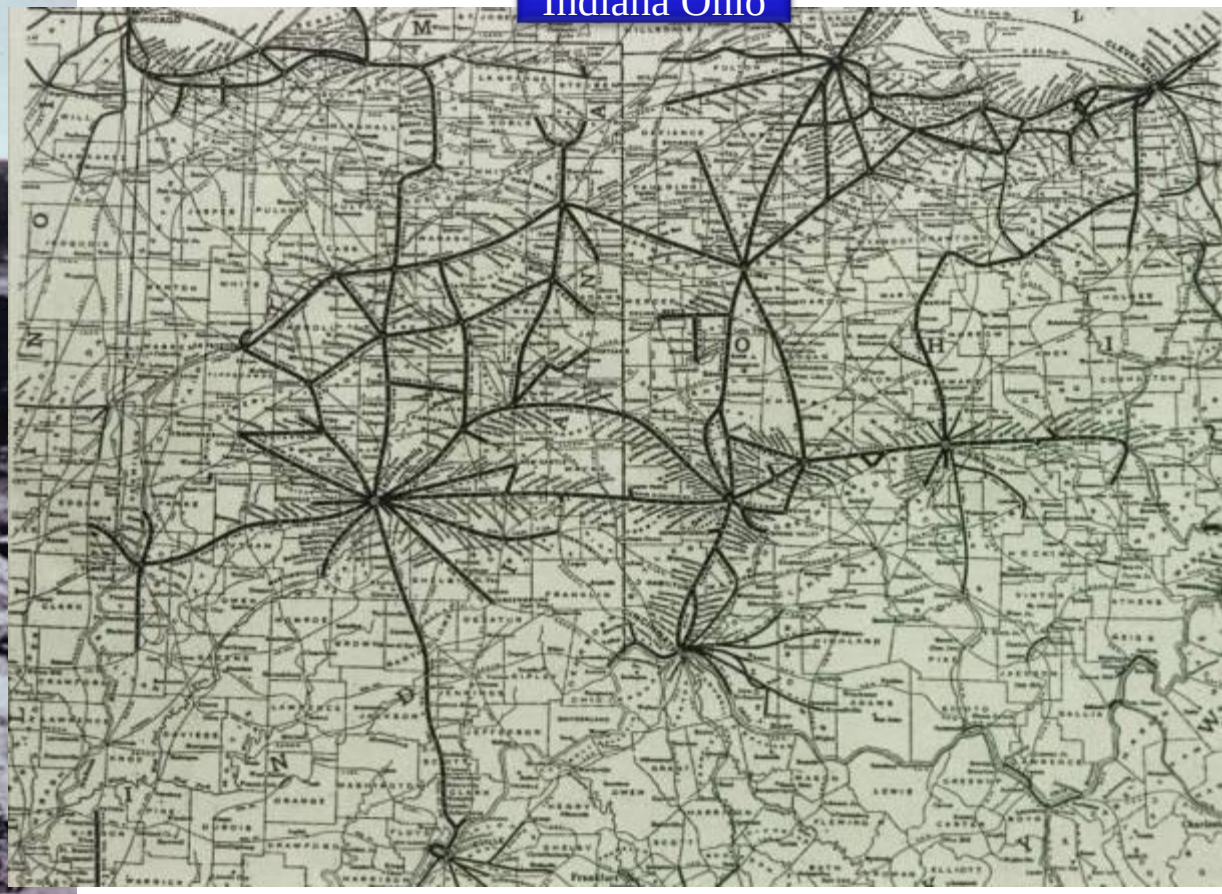
Growth to Maturity of Electric Traction

Build ‘em Everywhere

Iowa

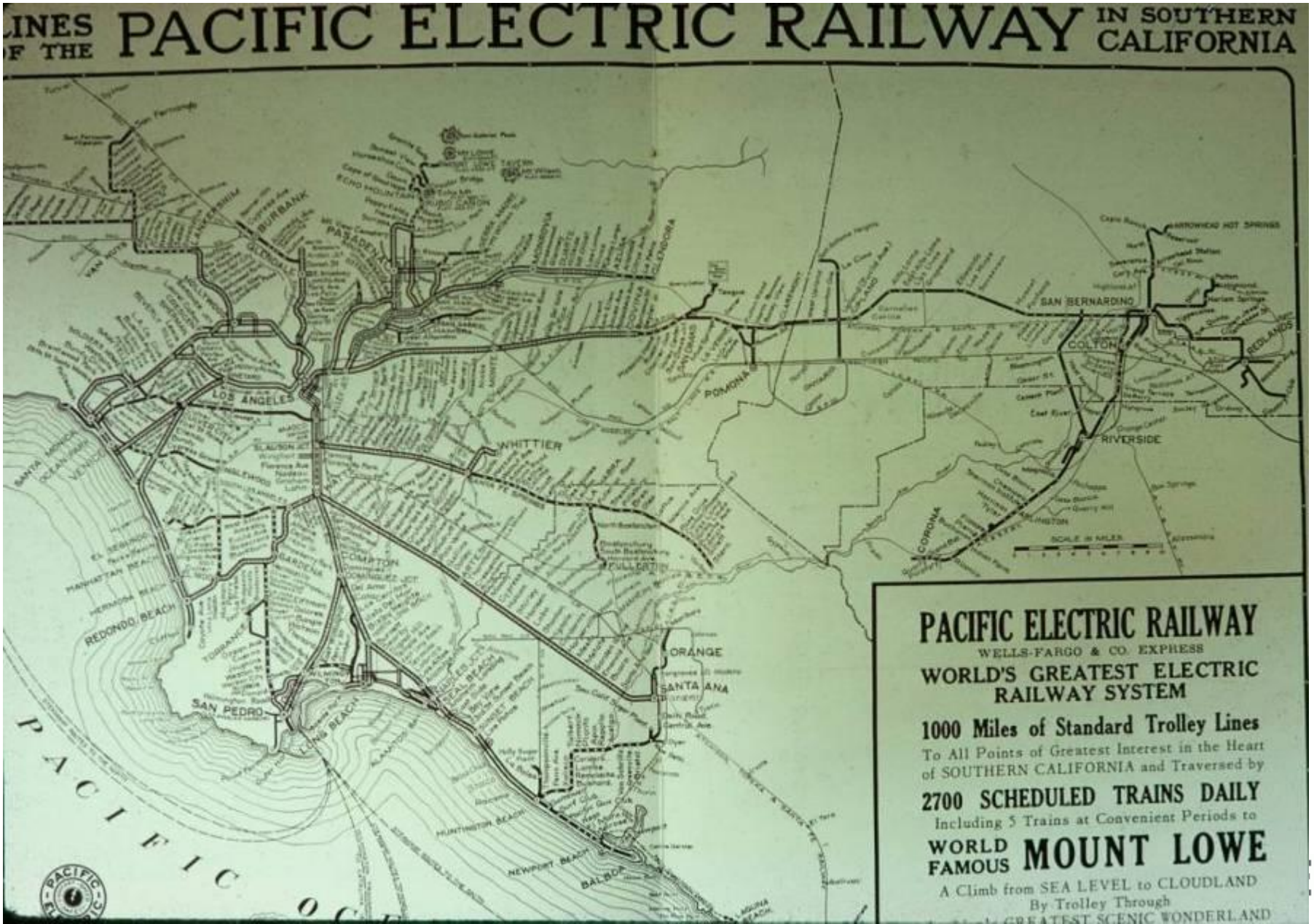


Indiana Ohio



Growth to Maturity of Electric Traction

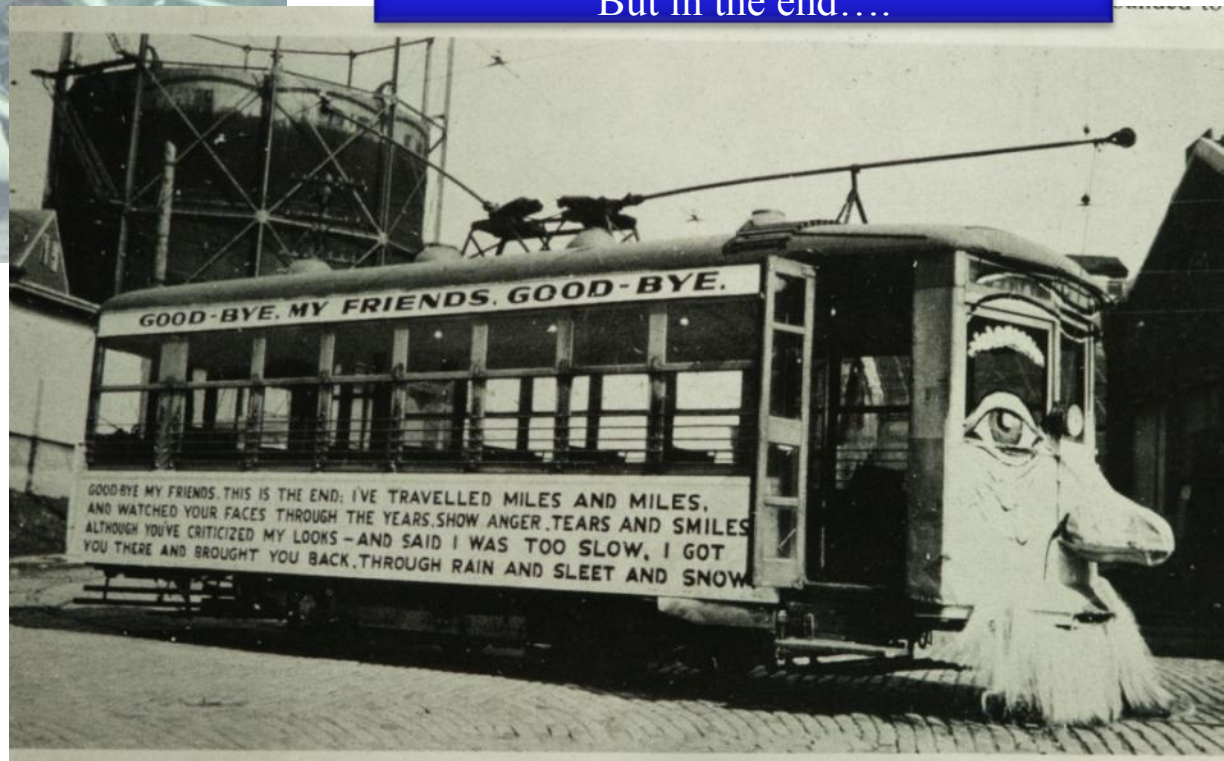
Build 'em Everywhere



Electric Traction

Putting the squeeze on the competition

But in the end….



s lugubrious and whiskered Birney made its final trip in Halifax, Nova Scotia, in 1949. Seven years earlier the streetcar
hat city had carried some 32 million people annually.

Death of Electric Traction

s lugubrious and whiskered Birney made its final trip in Halifax, Nova Scotia, in 1949. Seven years earlier the streetcar
hat city had carried some 32 million people annually

Death of Electric Traction

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Nostalgia of Electric Traction

Online sources of Light Rail Transit
- **Replicas of Vintage Trolley Cars: John Smatlak Link**
- **Light Rail, Tramway and Urban Transit Links Link**
- **Light Rail Transit Systems in US Link**

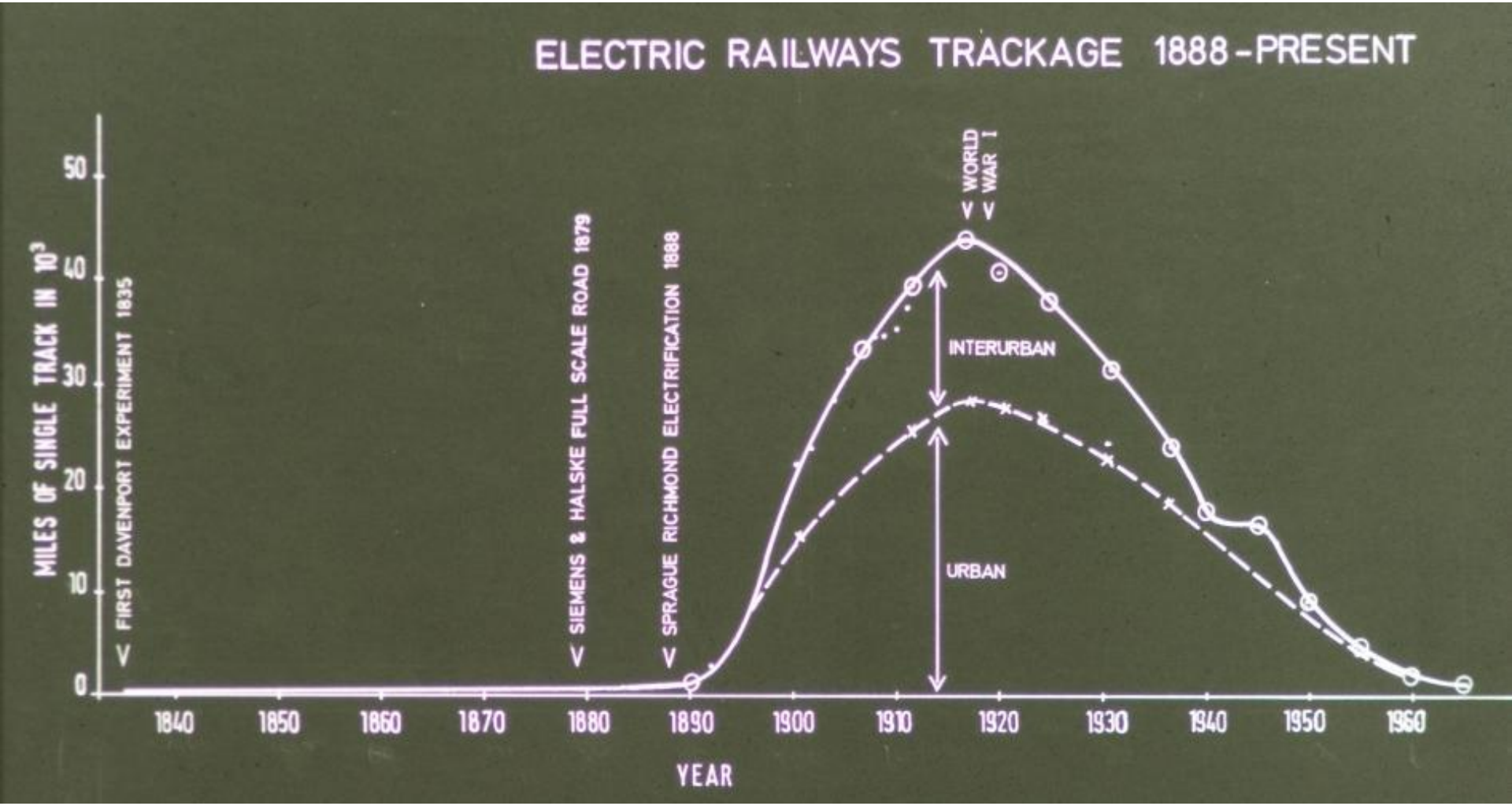
Pittsburgh

SF Muni

River Line NJ

Newark Subway

Growth to Maturity of Electric Traction



Jon Bell's Rail Transit Pages

Good source on many of his pictures and descriptions

Trolley Bus

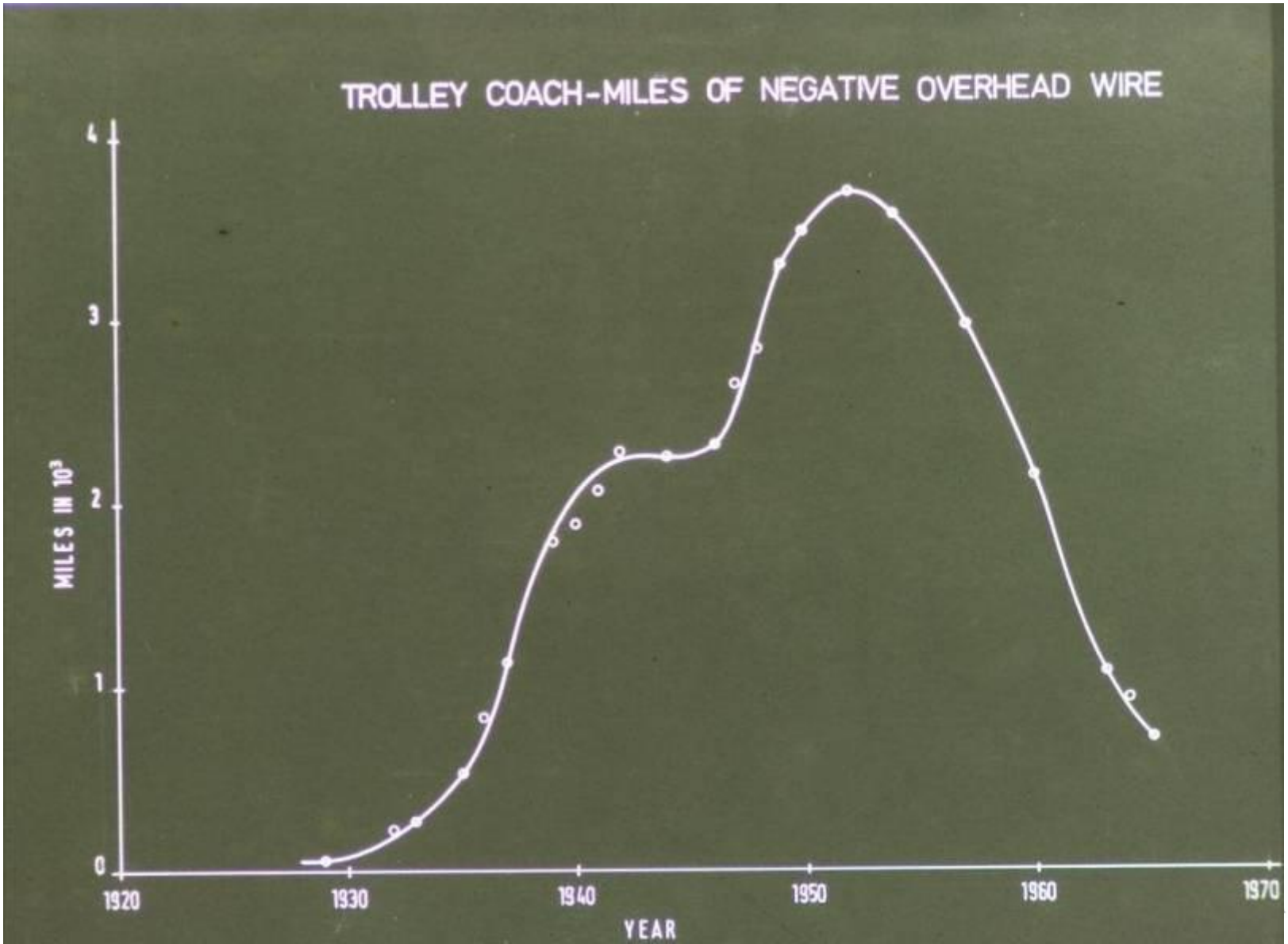
1st Trolley Bus
Von Siemens
Kurfurstendamm St., 1879

LA, 1912

Philadelphia, 1970

NYC 1930

Growth to Maturity of Electric Trolleys



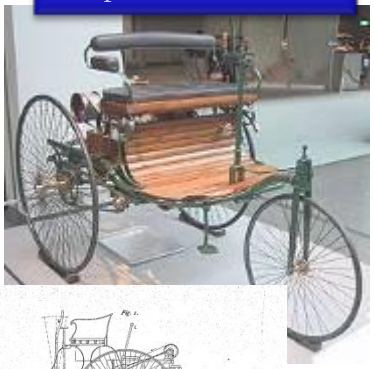
Early Innovators of the Automobile

Karl Benz 1844-1929

Nicolaus Otto (1832-1891)invented the first practical alternative to the steam engine in 1876 -- the first four-stroke internal combustion engine. He called it the "Otto Cycle Engine," and as soon as he had completed his engine, he built it into a motorcycle.

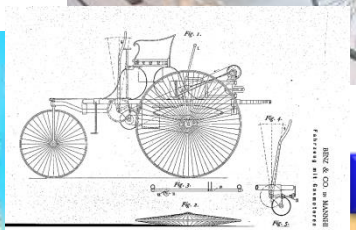
Gotlieb Daimler 1834-1900

Benz patent 1886 1st Automobile



1st Production Benz, Velo, 1894

Daimler Maybach Improved Ottos's Engine
1st Motorcycle 1885; 4-wheel automobile 3/8/1886



Wilhelm Maybach 1846-1929

1st bus (modified Benz Truck) 1895

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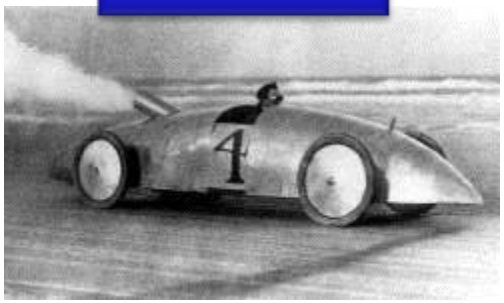
Early Innovators of the Automobile
Steam

Francis Edgar Stanley 1849 -1918
Freelan Oscar Stanley 1849 - 1940

1903 Mile Record



1908 Land Speed Record 127 mph

Part of the Tools of Racer After the Accident.

THE ACCIDENT TO THE STANLEY STEAM RACING CAR AT ORMOND BEACH.

1918 Stanley Steamer

1913 Stanley Steamer

Stanley Steamer Link Wiki

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Early Innovators of the Automobile

Electric

History of Electric cars

1900 Baker Electric

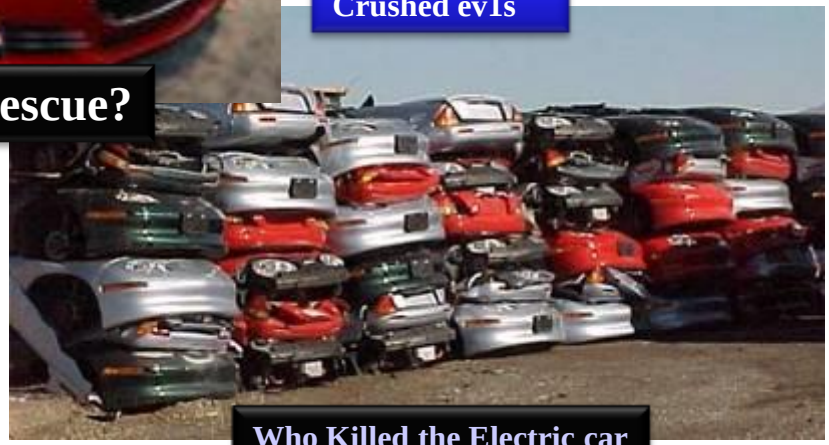
GM ev1 2000

Elon Musk to the rescue?

1905 Woods

Early electric cars

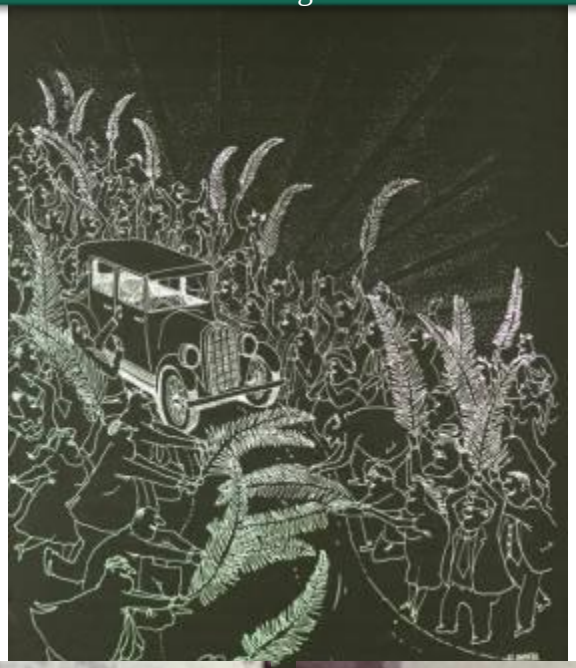
Crushed ev1s



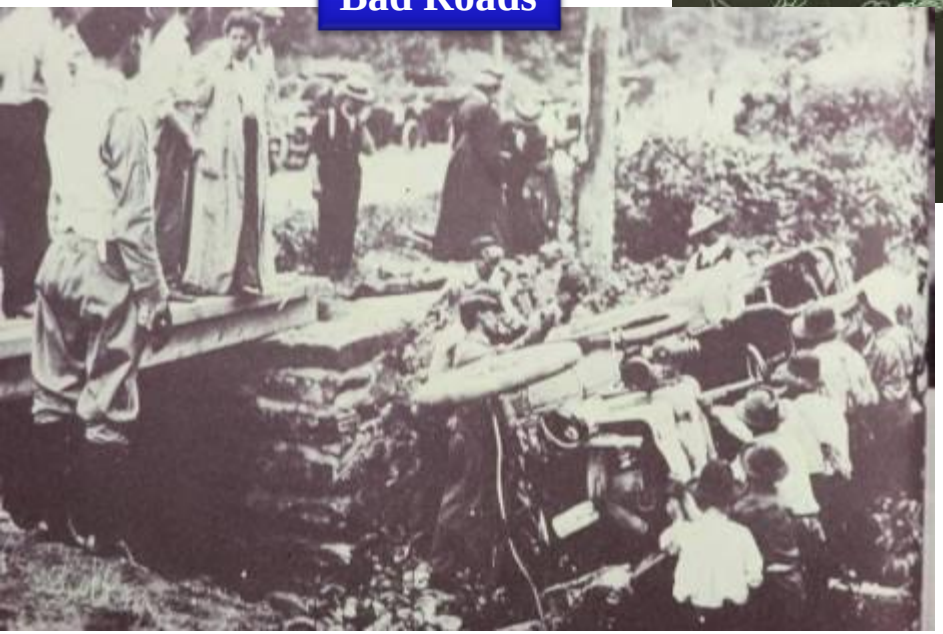
Who Killed the Electric car

Early Automobiles

Not so good!

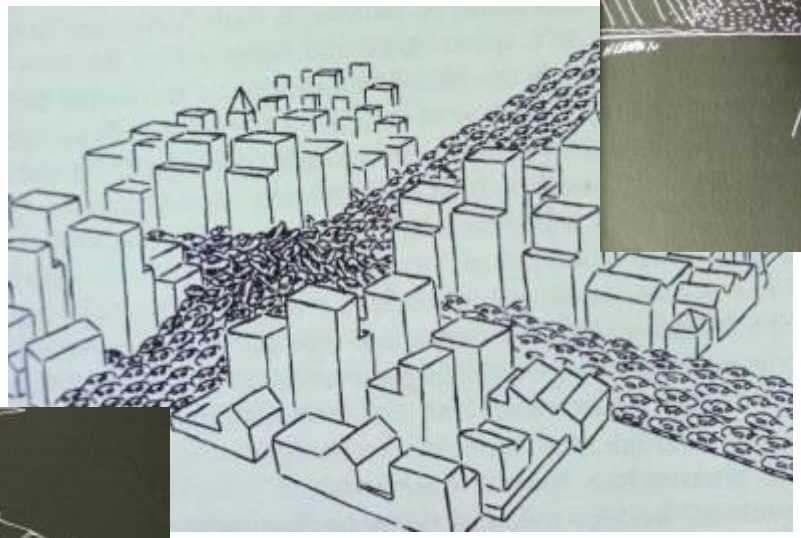


Bad Roads

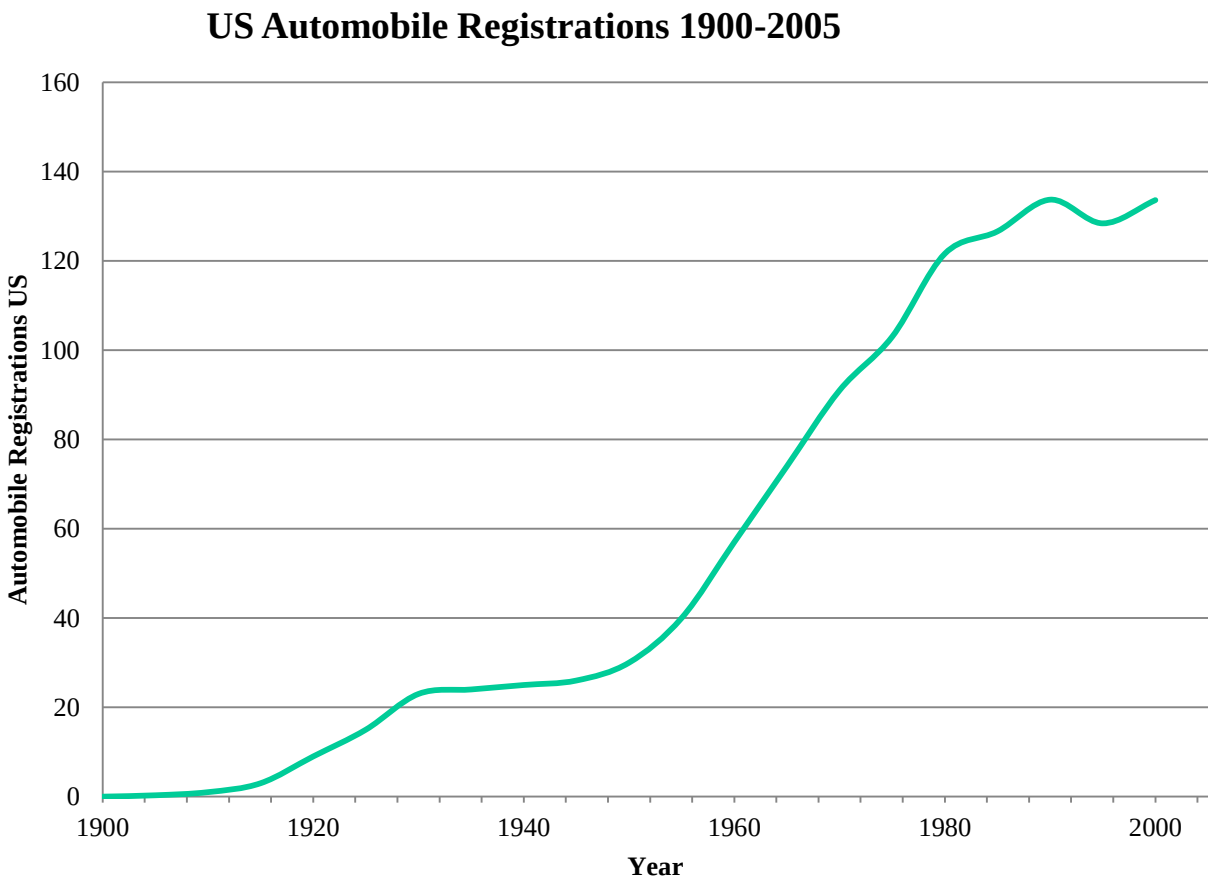


Bad Weather

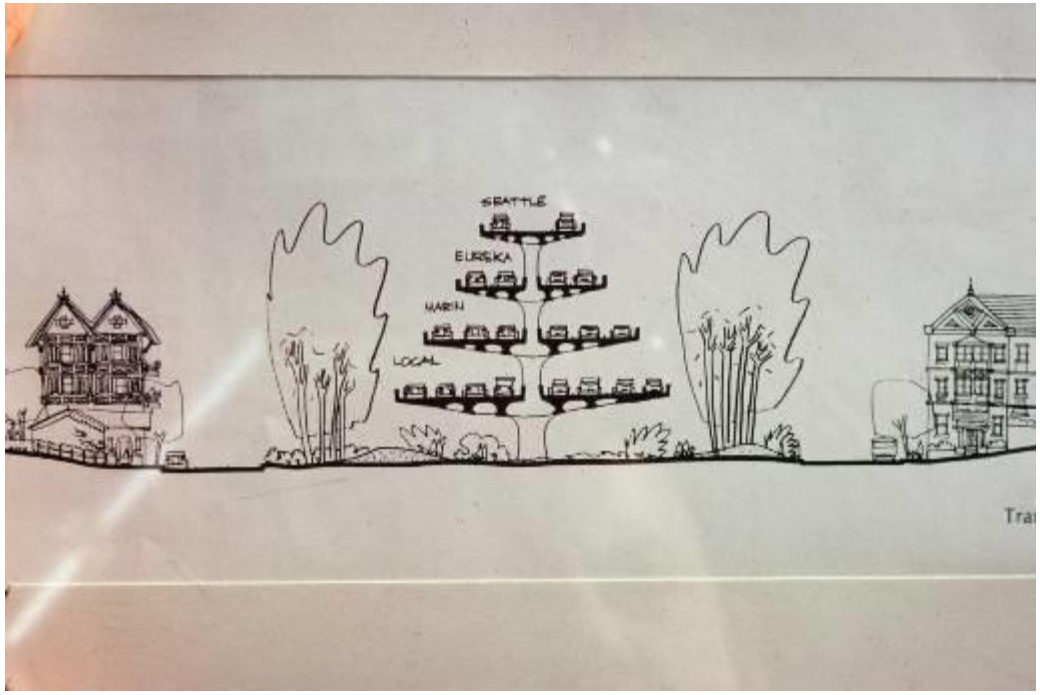
Dominance of Automobiles



Dominance of Automobiles



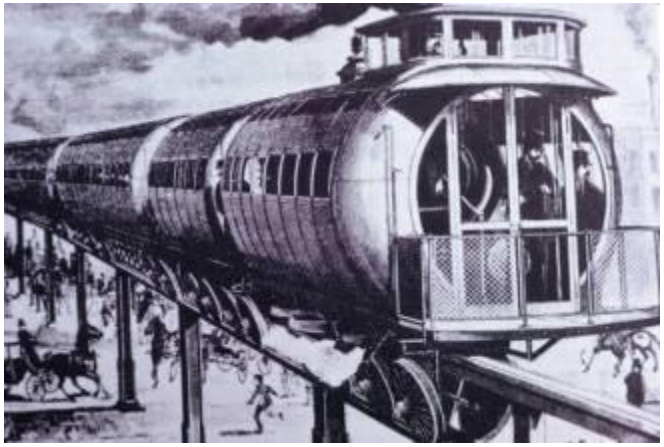
Innovative Solutions

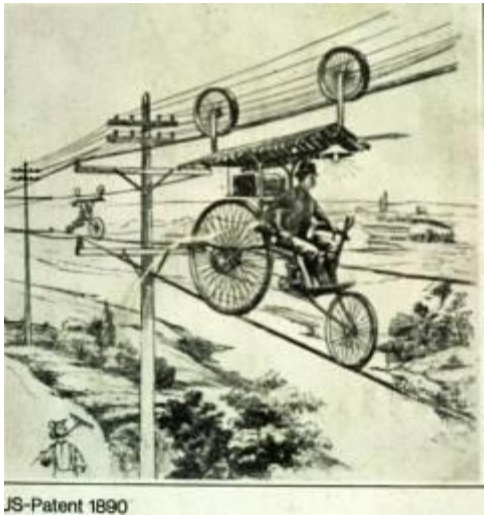


What about Mass Transit??

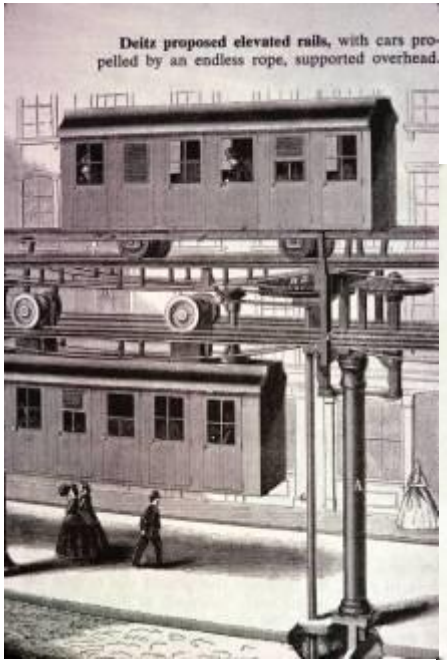
Do you mean Monorails??

MonoRails: Not a new concept Suspended

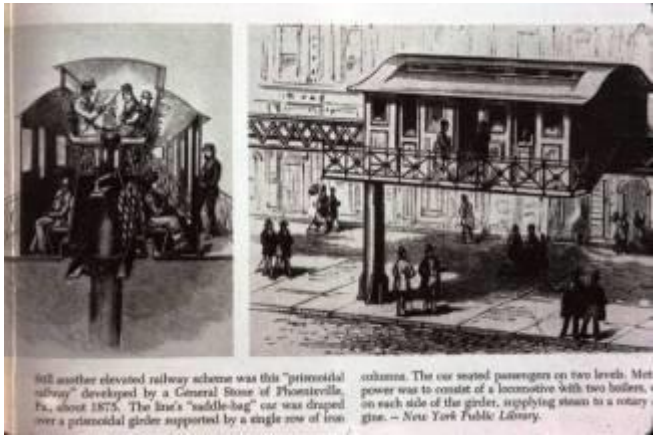




1886, Cambridge Line

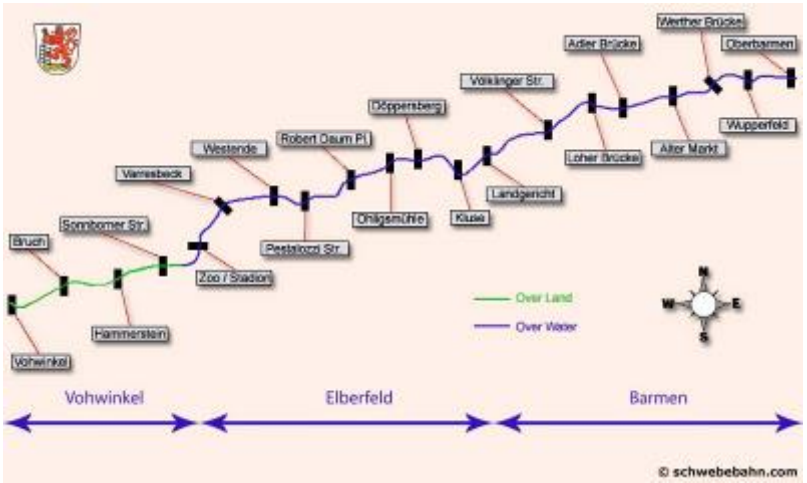


End of a bright dream: a wrecking crew props up the toppled Pelham Bay monorail car. Note the single rail on the ground.



Wuppertal Schwebebahn

- 8.3 miles
- 20 stations
- 22.9 M pax/yr
- 72,000 pax/day
- Av occupancy 52.8%
- 2.9 miles Av.Travel Distance
- .03632 kWh/pax

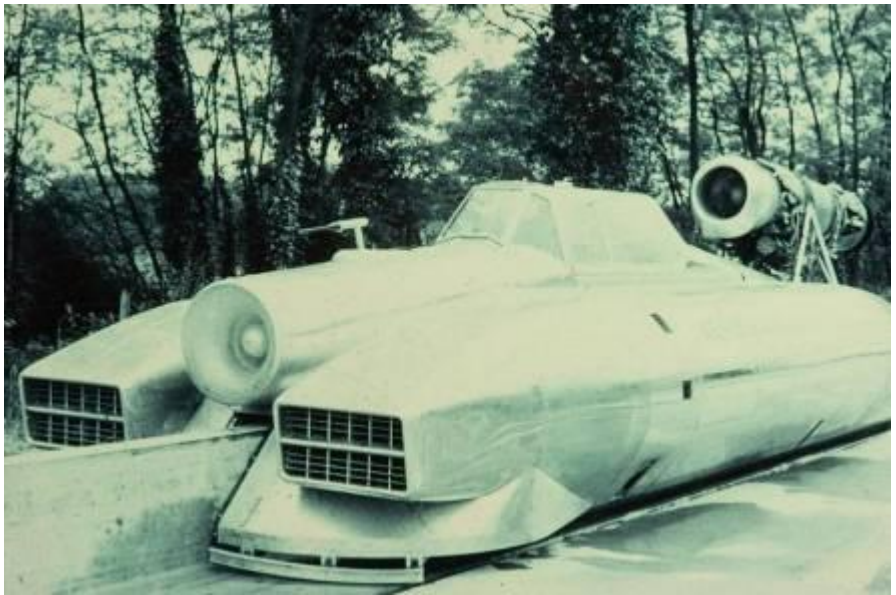


Movie

ORFE

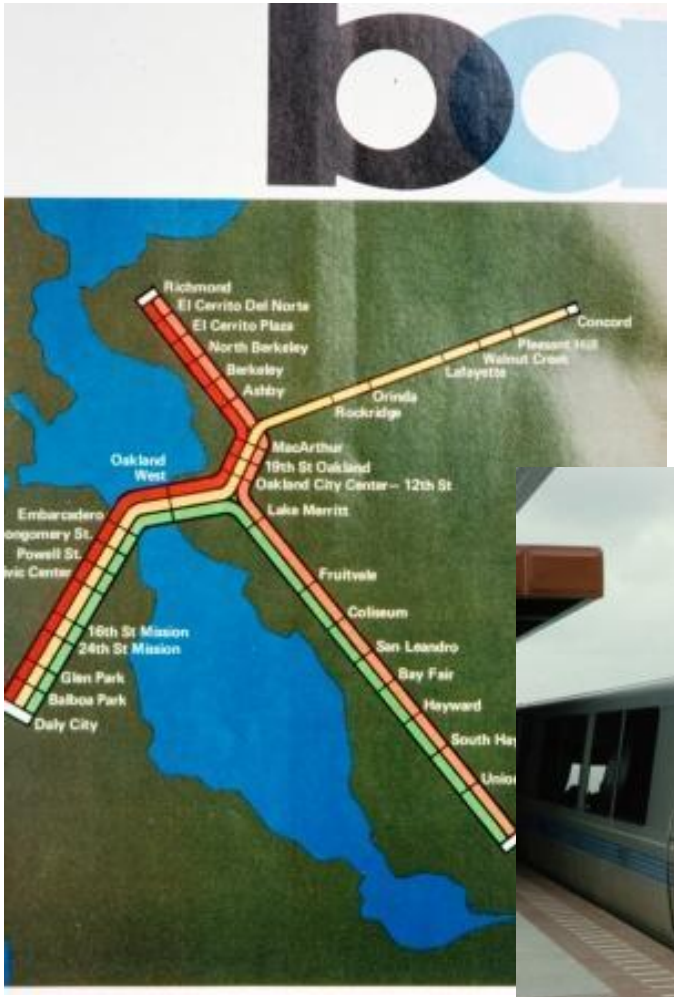
MonoRails: DisneyWorld

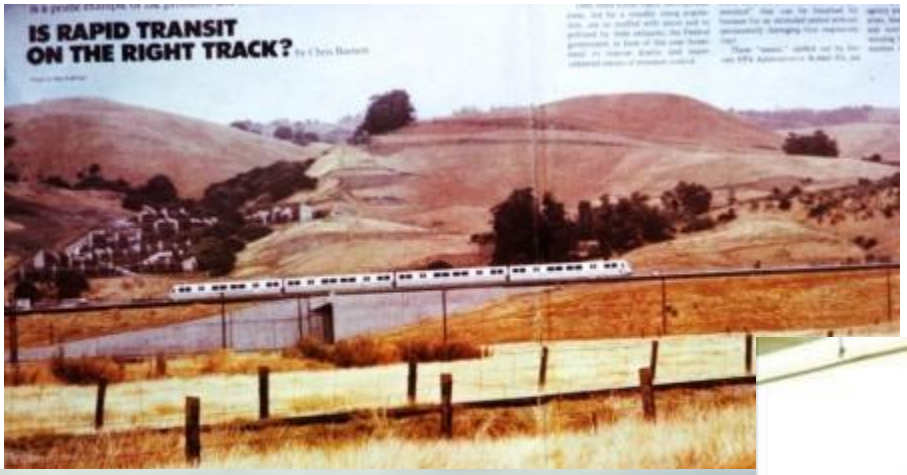
Alternative Propulsion: You've got to go FAST!



Automated Systems Commuter Rail

BART





Automated Systems
Commuter Rail

Lindenwold NJ Line

Automated People Movers

**Westinghouse SkyBus,
South Park Test Track Pgh, Pa**

Automated People Movers

Westinghouse SkyBus, South Park Test Track Pgh, Pa

Tampa Airport

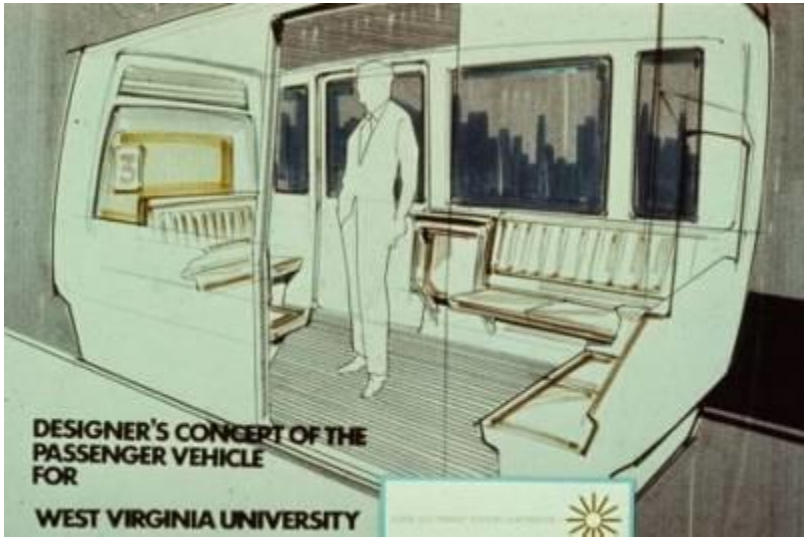
Morgantown PRT
(On the vehicle switch!)
(actually: Group Rapid transit (GRT))

Starts with Alden Starr car

Morgantown PRT

Morgantown PRT

Morgantown PRT



Morgantown PRT

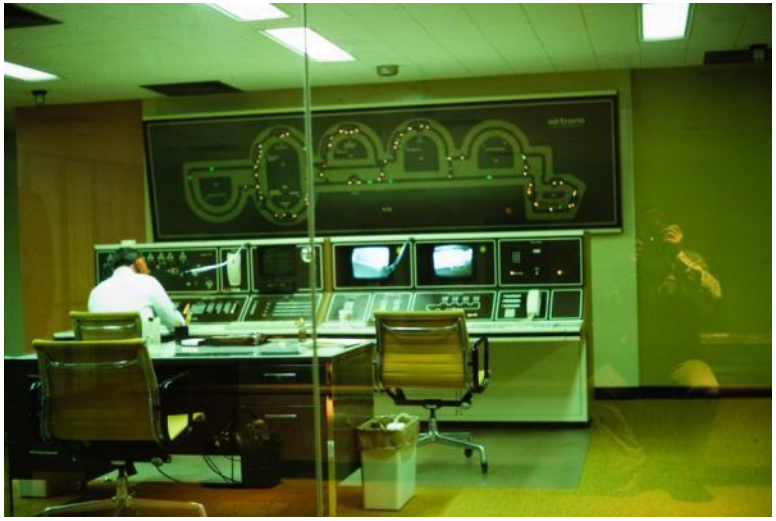
Morgantown PRT

Movie

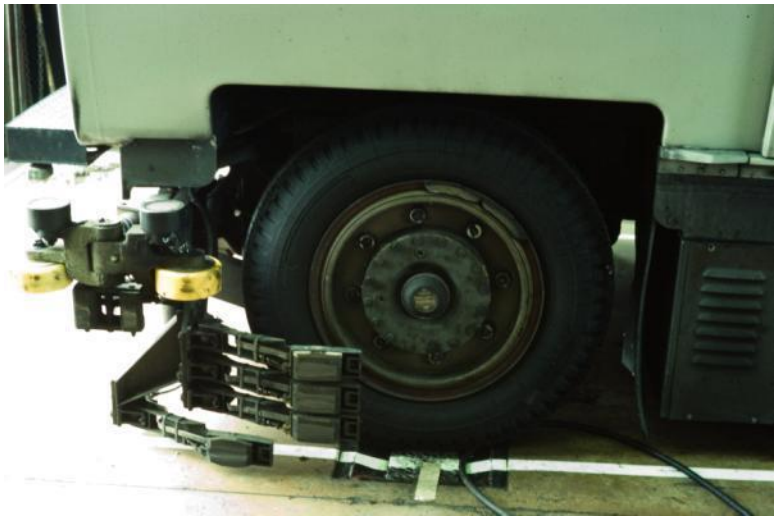
Movie2

Morgantown PRT

DFW AirTrans PRT



DFW AirTrans PRT



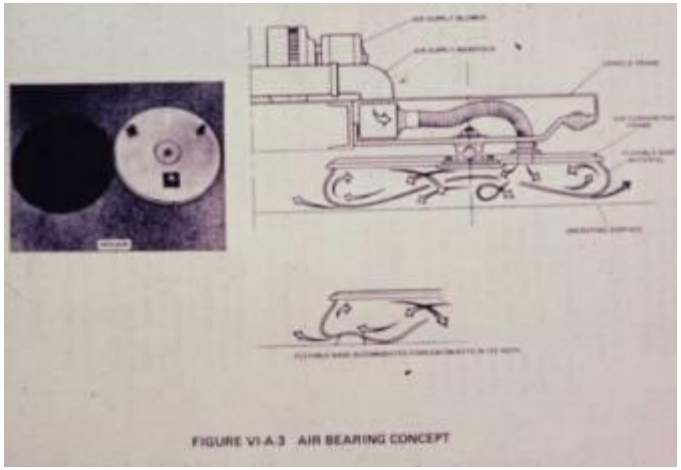
airtrans VOUGHT

D/FW OPERATIONS AND MAINTENANCE STAFF

MANAGEMENT AND ADMINISTRATION	3
PURCHASING AND SUPPLY	9
ENGINEERING	3
OPERATORS	11
MAINTENANCE	84
TOTAL	110
AVERAGE STAFF ON DUTY DURING ANY SHIFT = (24 TO 28 TRAINS IN OPERATION)	20

Alternative Support
Air Bearing

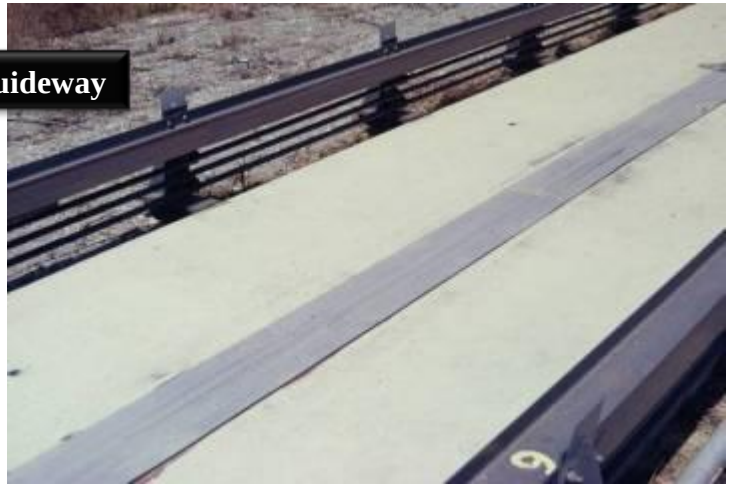
Transportation Technology, Inc. (TTI) -Otis



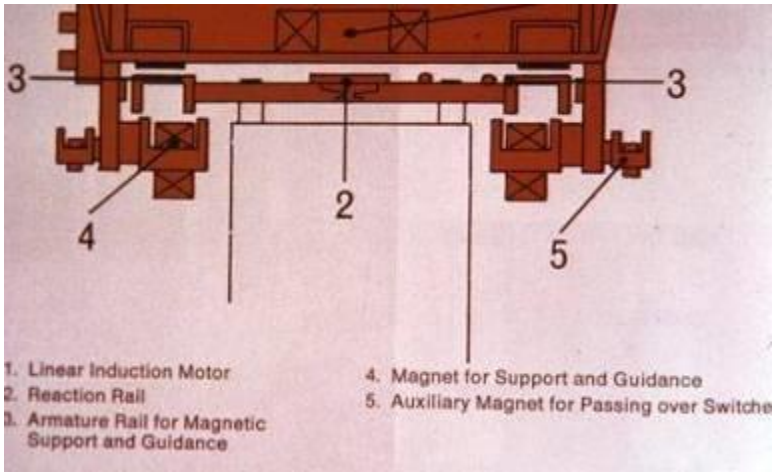
Compatible with:
- **On-vehicle switch**
- **Linear induction propulsion**
- **Low Floor**

Active element of LIM in guideway

Passive element of LIM in guideway



Alternative "Support": Attractive Mag lev



Alternative “Support”: Overhead Suspended

Rohr Monocab

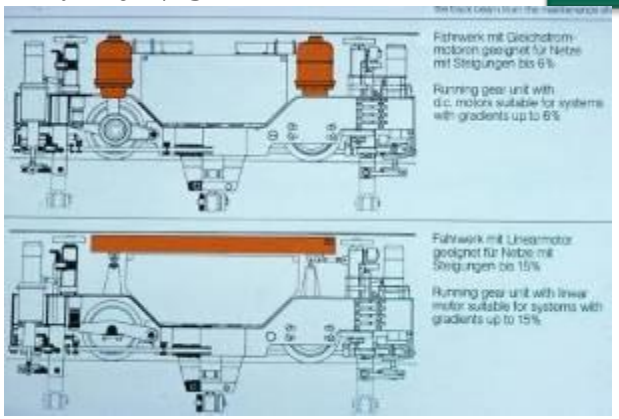
Alternative "Support": Overhead Suspended

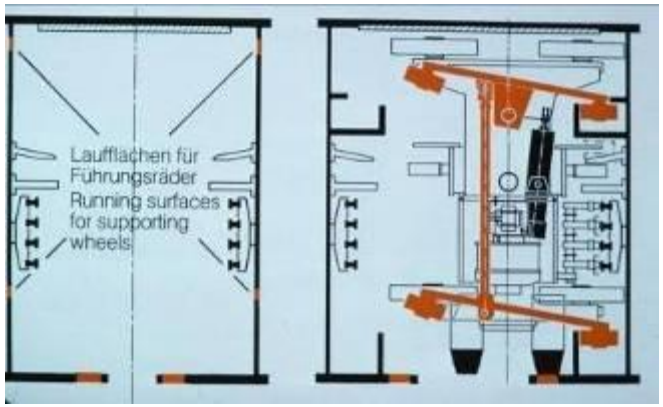
Rhor Monocab

Alternative "Support": Overhead Suspended

Rhor Monocab

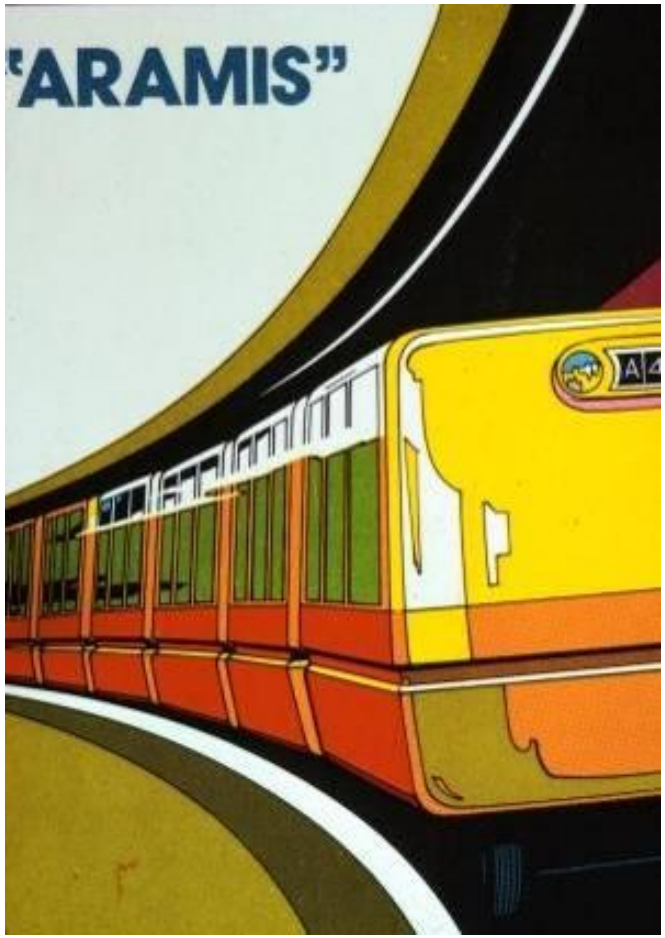
Alternative "Support": Overhead Suspended H-Bahn





Alternative Headway Control

Laser range



Alternative Headway Control

Aramis

Alternative "Support": "Both" CabinenTaxi

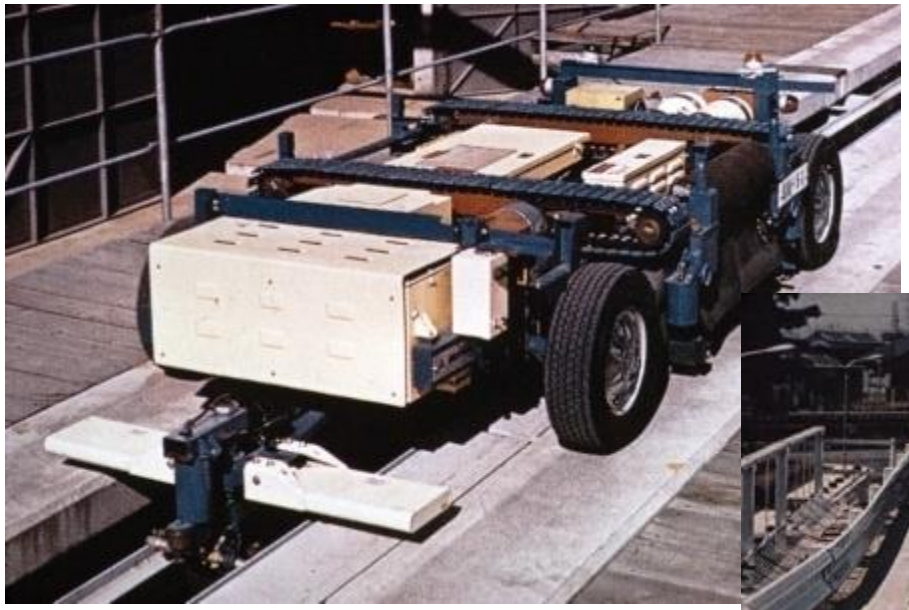
Alternative “Support”: “Both” CabinenTaxi

Alternative "Support": CVS

(Bullet through the propeller trick)

Alternative "Support": CVS

(Bullet through the propeller trick)



~40 years ago…

- Morgantown

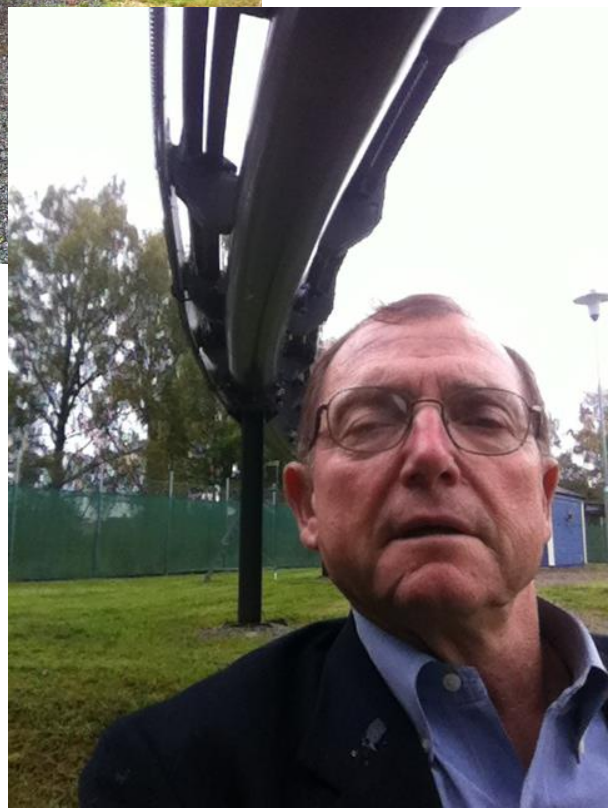
Along the way…

Nothing much…

Current PRT Innovators:

Vectus

Link & Video



And Today…

Masdar (2GetThere) & Heathrow (Ultra) are operational

Video

Today…

Morgantown 1975

Remains a critical mobility system today & planning an expansion

- PRT: Tough business case:
  - Segregated guideway too often needs to be elevated
    - Tends to pass by bedroom windows
    - Tough sell at public meetings
    - Guideway is Expensive
  - Small initial systems tend to be in areas of high demand
    - While a small vehicle system would work, so will a larger vehicle system, which has less risk
      - Example: airports, large APM (Automated People Mover) just fine even though they have no expansion potential (nor does the "owner" have expansion desires)
    - Therefore, not easy to get started.

- Automation of Road Vehicles
  - Automated Highways (1939 -> 1999)
    - Automated vehicles on exclusive automated highways
      - Tough business case:
        - » no one will build an automated highway if there are no cars to run on it
        - » No one will buy an automated car if it doesn't have any roads to run on
        - » (Henry Ford lobbied hard (created a film & "propaganda" subsidiary) to have "Farm2Market" roads built throughout the country so that buyers of his cars & trucks would have somewhere to drive them.
    - National Automated Highway System Research Program (1992~1997)
      - **National Automated Highway System Research Program *A Review***
- AN OVERVIEW OF AUTOMATED HIGHWAY SYSTEMS (AHS) AND THE SOCIAL AND INSTITUTIONAL CHALLENGES THEY FACE

- Automation of Road Vehicles
  - Concept of Automated Vehicles Sharing Roadways with Conventional Human-driven Veicles (1994 ->)
    - I suggested the concept during the National Automated Highway System Research Program (1992~1997); however, it wasn't pursued.
    - Concept gained some traction during DARPA Challenges (2004,5,7)
    - Concept Propelled by Google's initiative to develop "Driverless-car" starting in 2010.
    - NHTSA "Automation "Levels"
      - (Level 0 (no automation) through Level 4 (driverless)
        - » Google: "Level 4" Product Market ready by 2018
        - » Nissan: 2 "Level 4" Models in showroom by 2020
        - » Volvo: Zero deaths by 2020
    - www.SmartDrivingCar.com

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