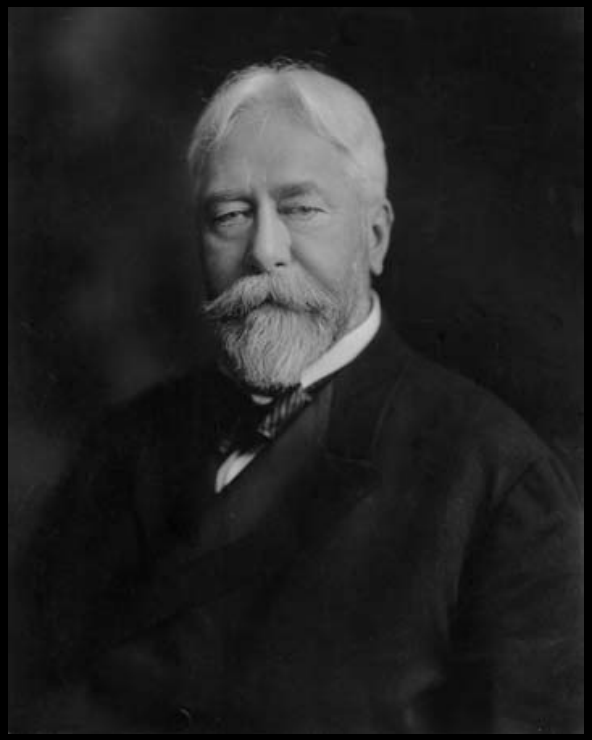
Othmar Ammann and the George Washington Bridge

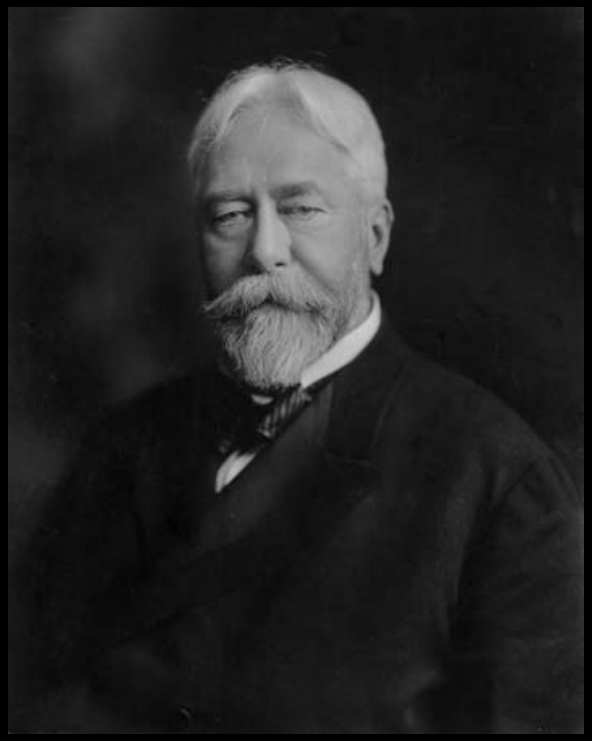
Iconic bridge with thin deck – First Interstate Compact
World's longest suspension bridge – doubling previous record

CEE 102: Prof. Michael G. Littman
Course Administrator: Arianna Sherman ariannas@princeton.edu

Computers for NOTETAKING ONLY
Please - NO Cell Phones, Texting, Internet use

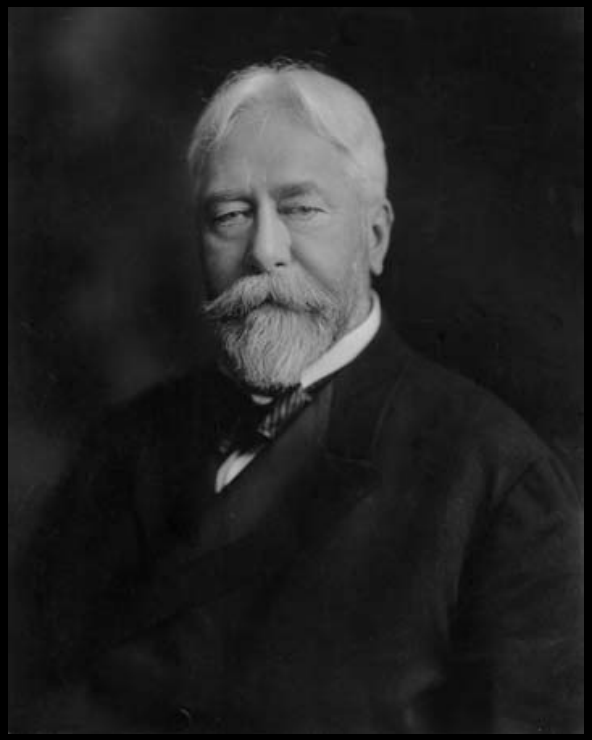


Gustav Lindenthal
(1850 – 1935)
19th Century Engineer
Railroads



Gustav Lindenthal
(1850 – 1935)
19th Century Engineer
Railroads

Othmar Ammann
(1876 – 1965)
20th Century Engineer
Automobiles



Gustav Lindenthal
(1850 – 1935)
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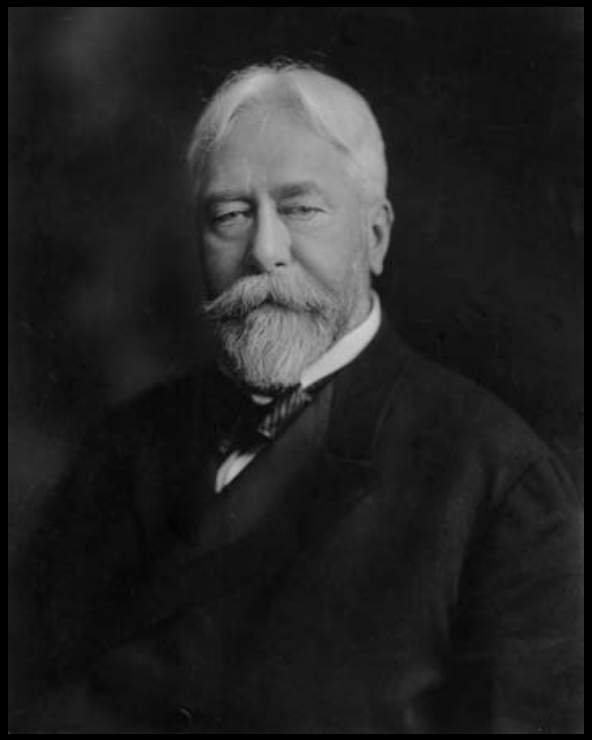
Railroads

STRUCTURES

Static

Custom-made

Public Works



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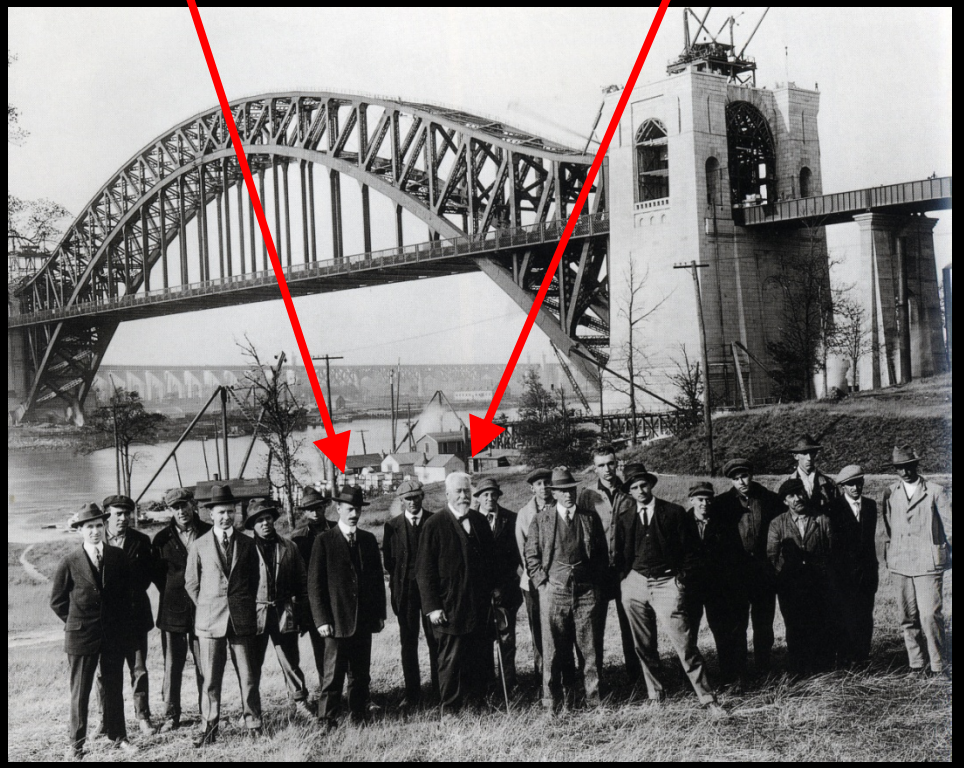
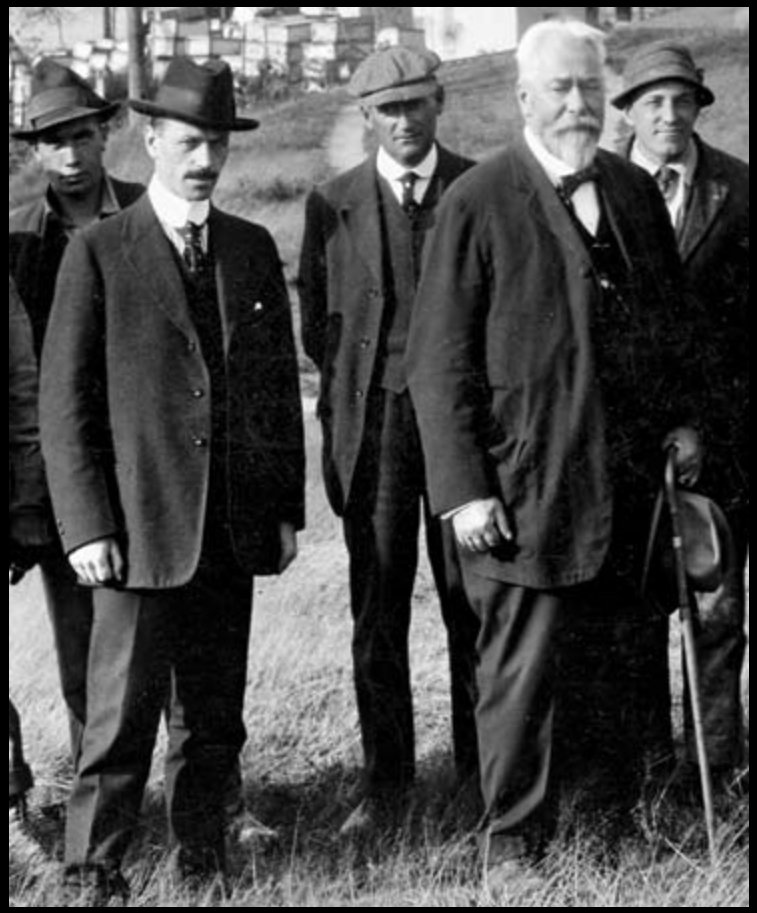
Ammann

Lindenthal

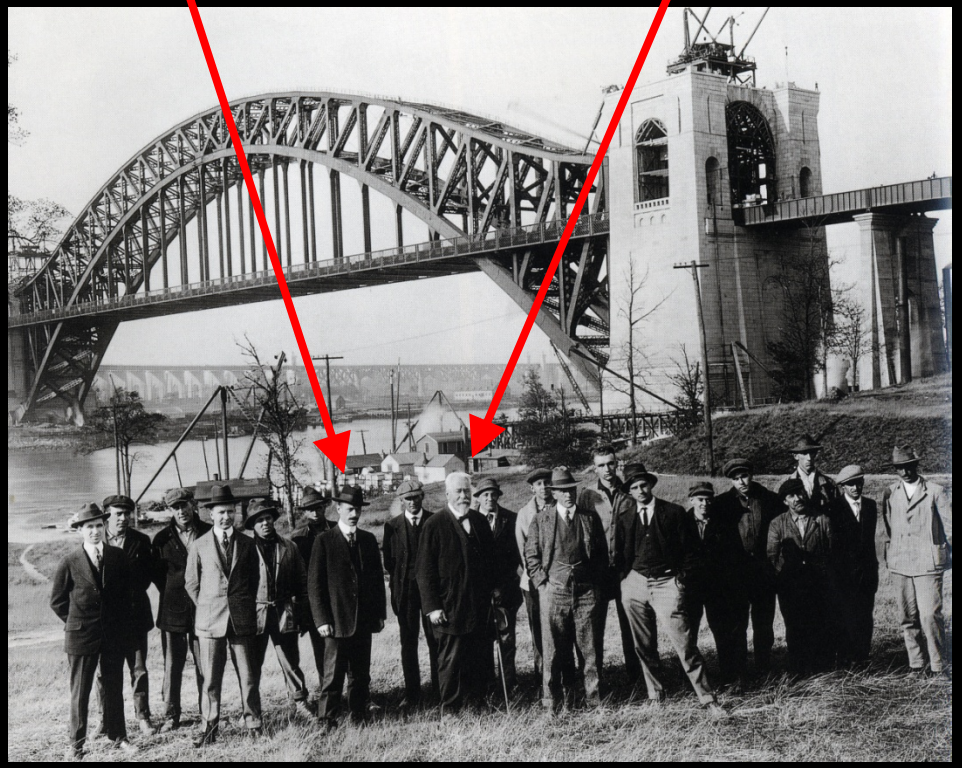


Hell Gate PRR Bridge - 1917



Ammann

Lindenthal



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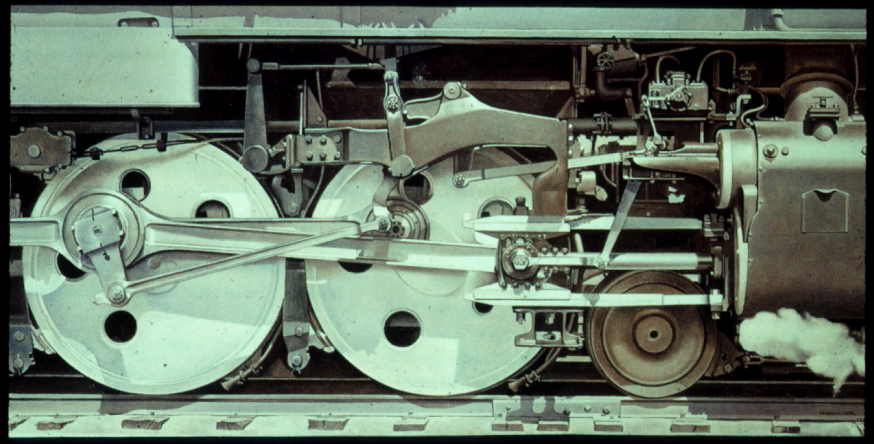

Ammann

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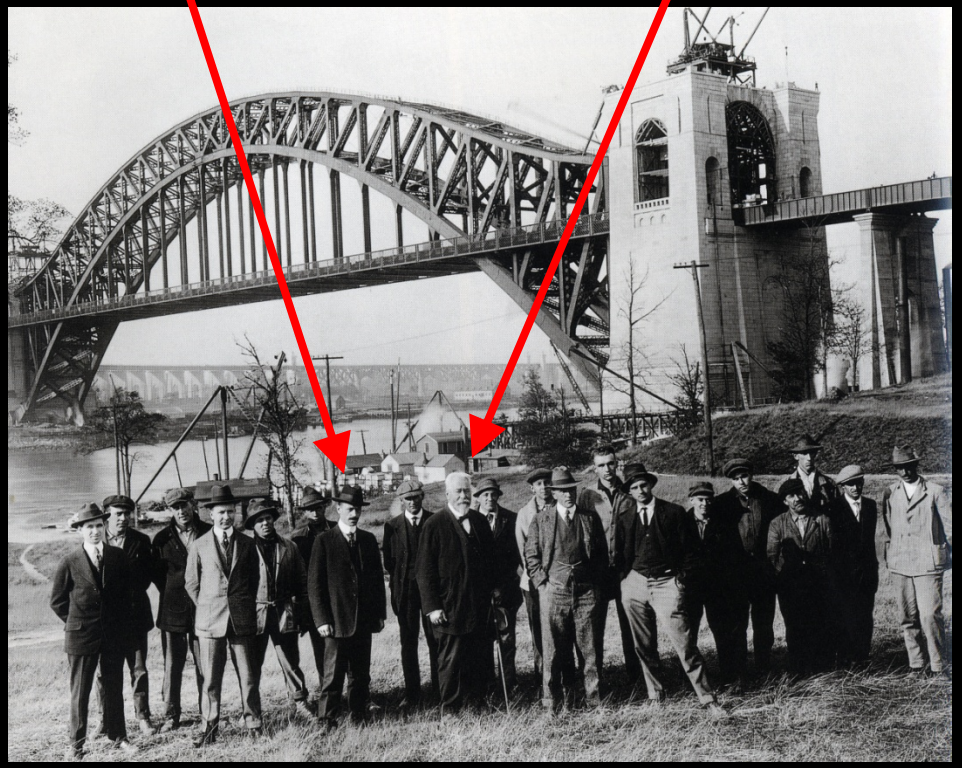
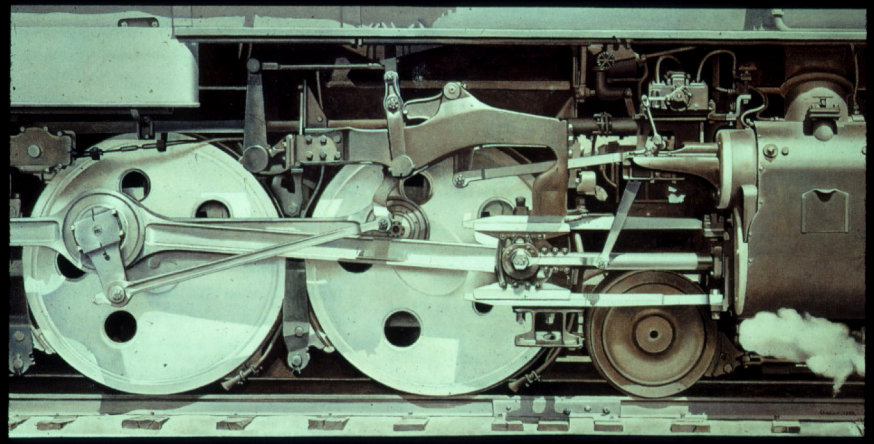


Hell Gate PRR Bridge - 1917

Lionel Scale-Model Bridge



Ammann

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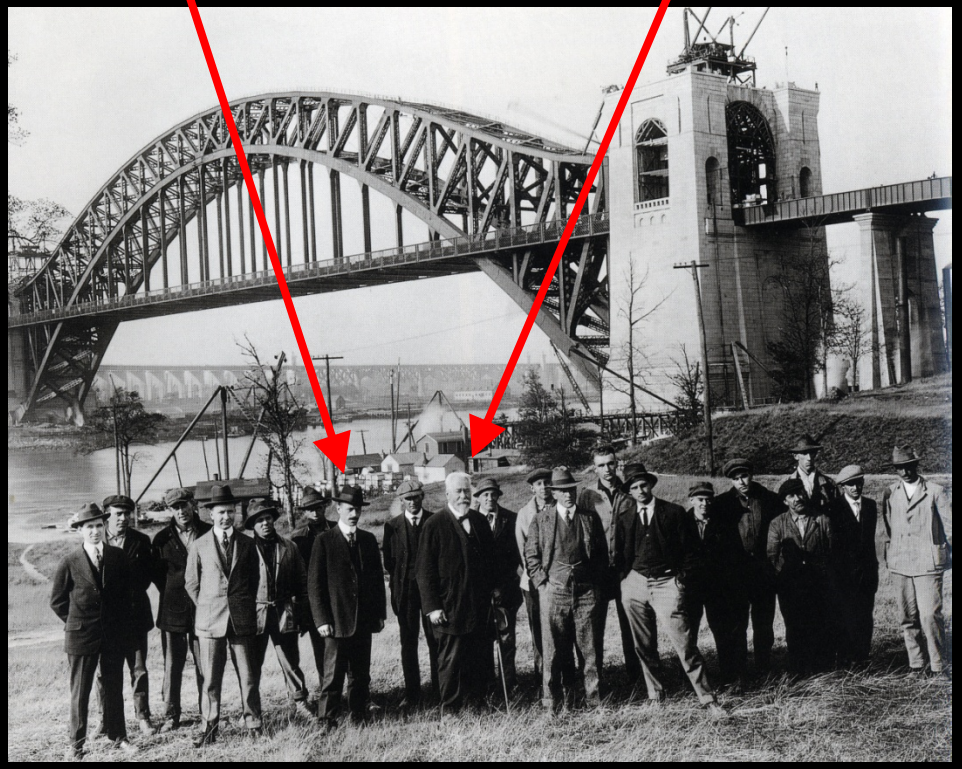
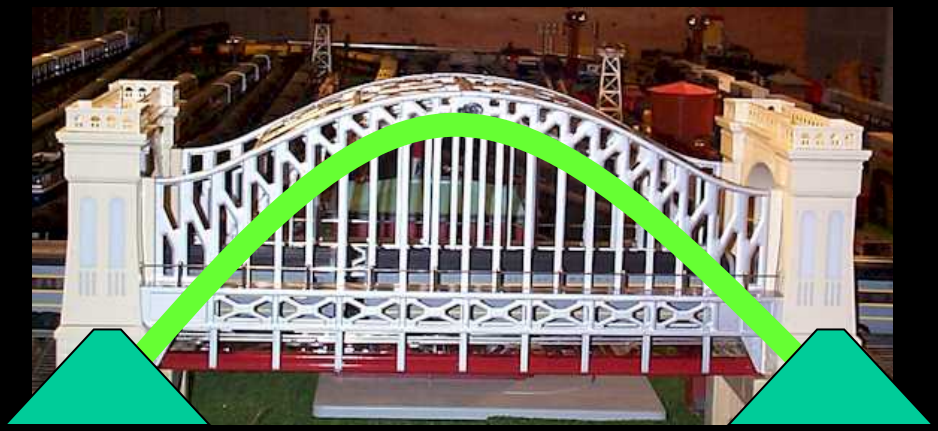
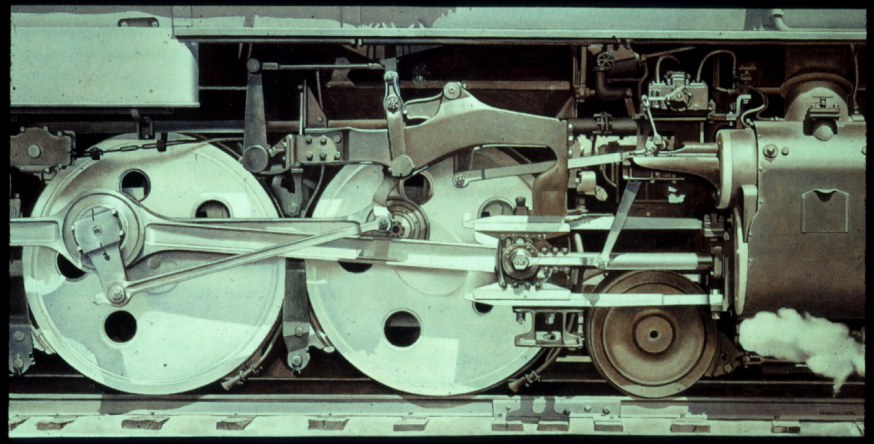


Hell Gate PRR Bridge - 1917





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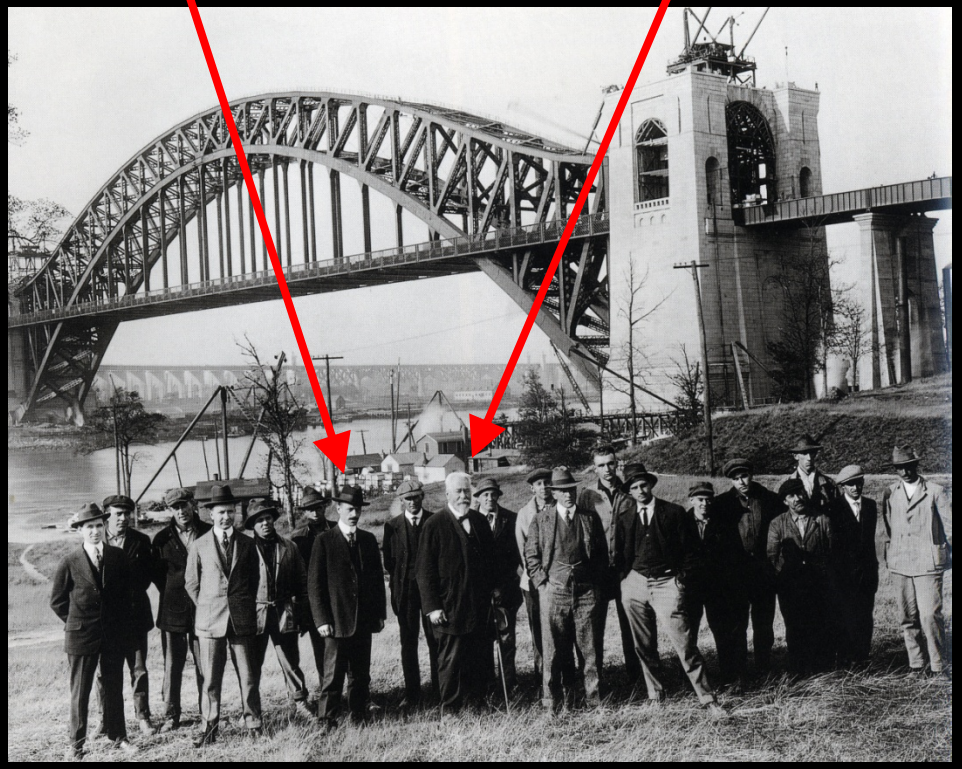

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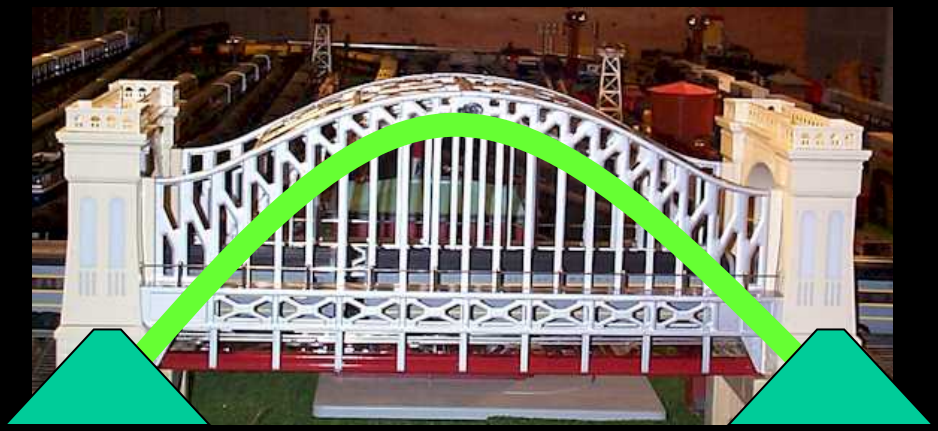

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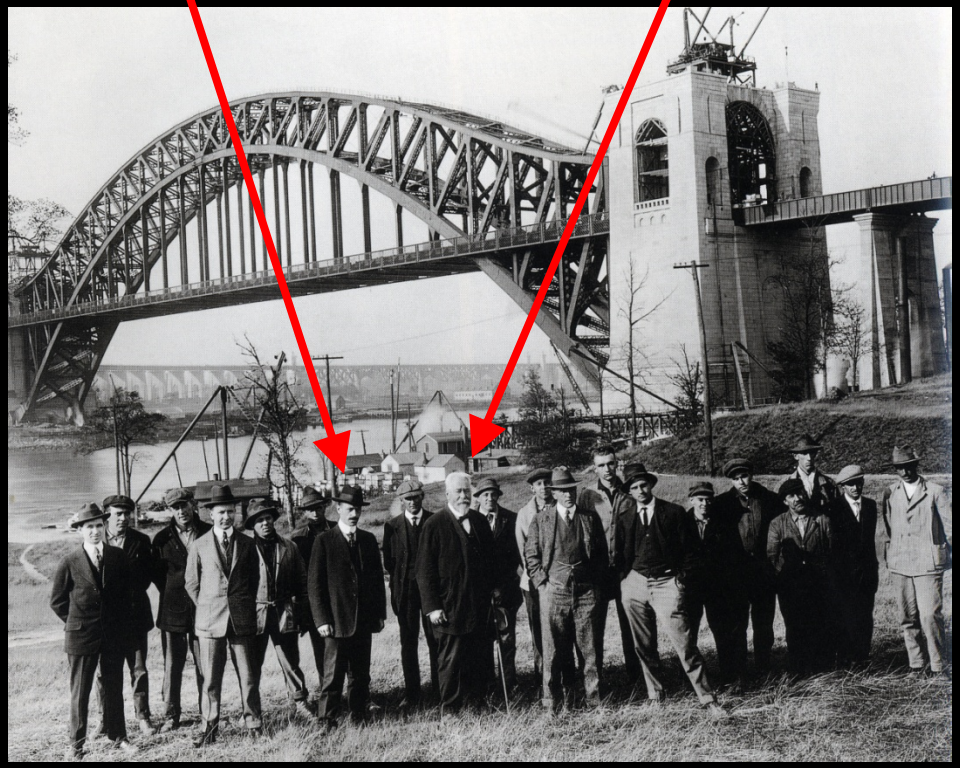
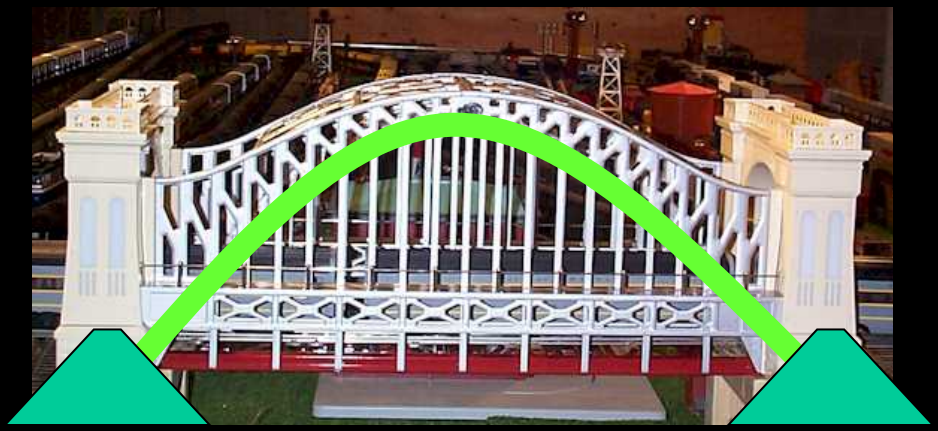
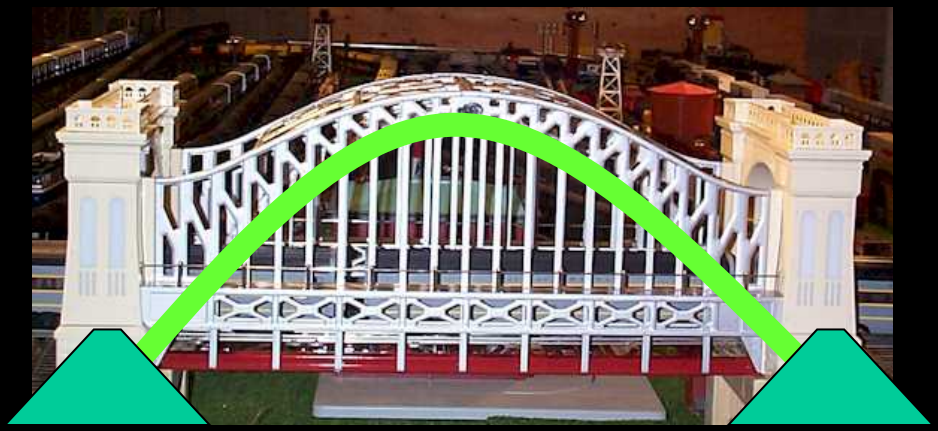


Hell Gate PRR Bridge - 1917



Hell Gate PRR Bridge - 1917
Worlds' longest arch - 1017 ft



Market Street Bridge - 1917

Regional Restructuring (1914 – 1964)

congested region	Metropolitan New York	Hudson River
depressed region	Tennessee Valley	Tennessee River
undeveloped region	Southwestern United States	Colorado River
inaccessible region	Pacific Ocean Panama	Chagres River

Market Street Bridge - 1917

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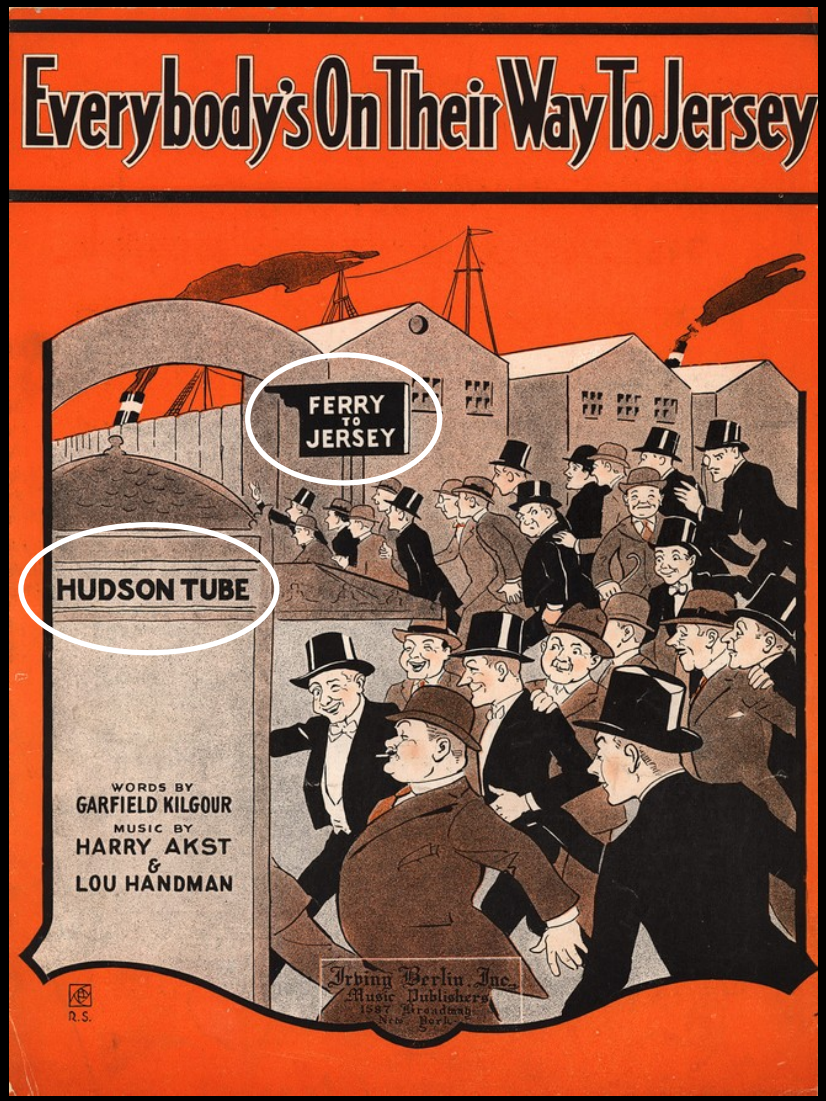
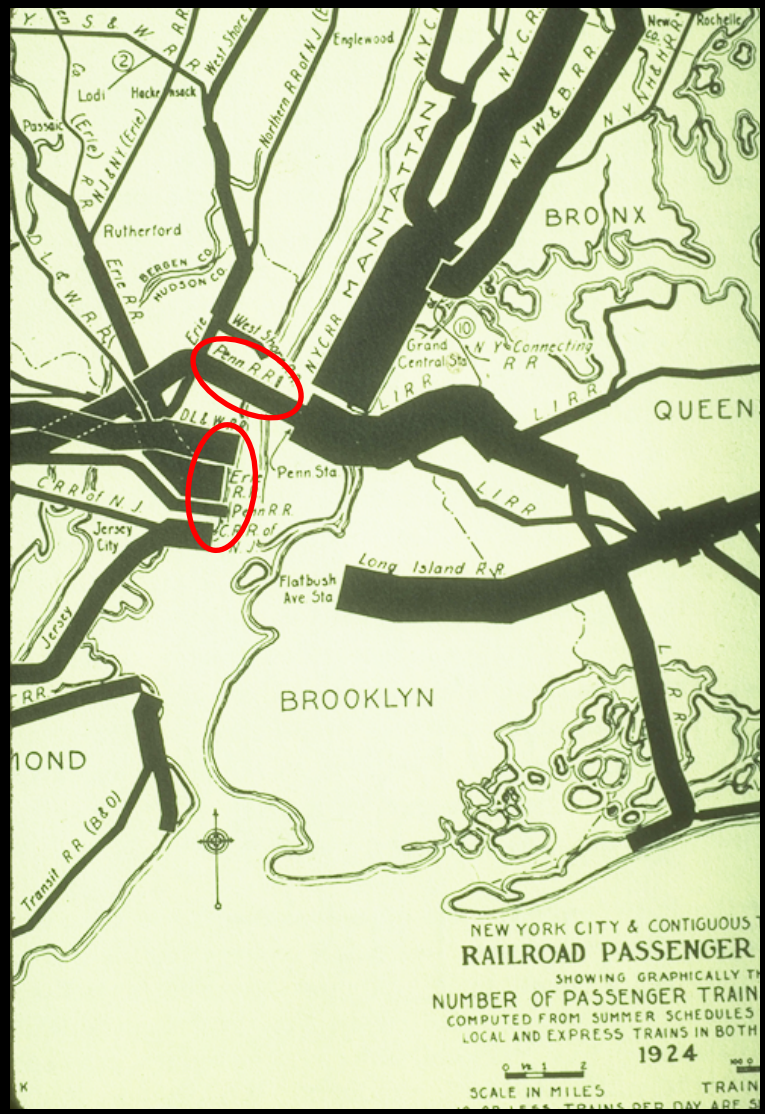
Railroad Ferry – Hoboken NJ





"People living there are fine, each one has a friend named Stein …"

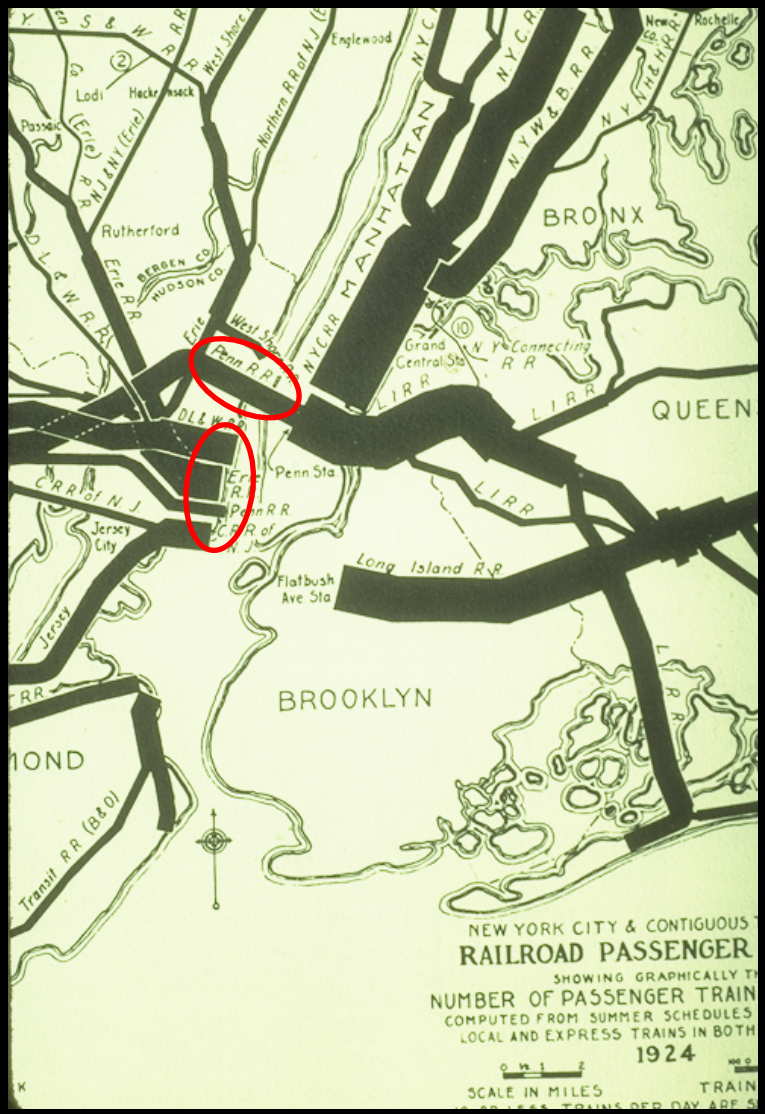
Prohibition 1920 - 1933

Port of New York Authority

1909 - Port of London Authority

1917 - Harbor Development Commission of NY and NJ

1921 - Port of New York Authority



Port of New York Authority

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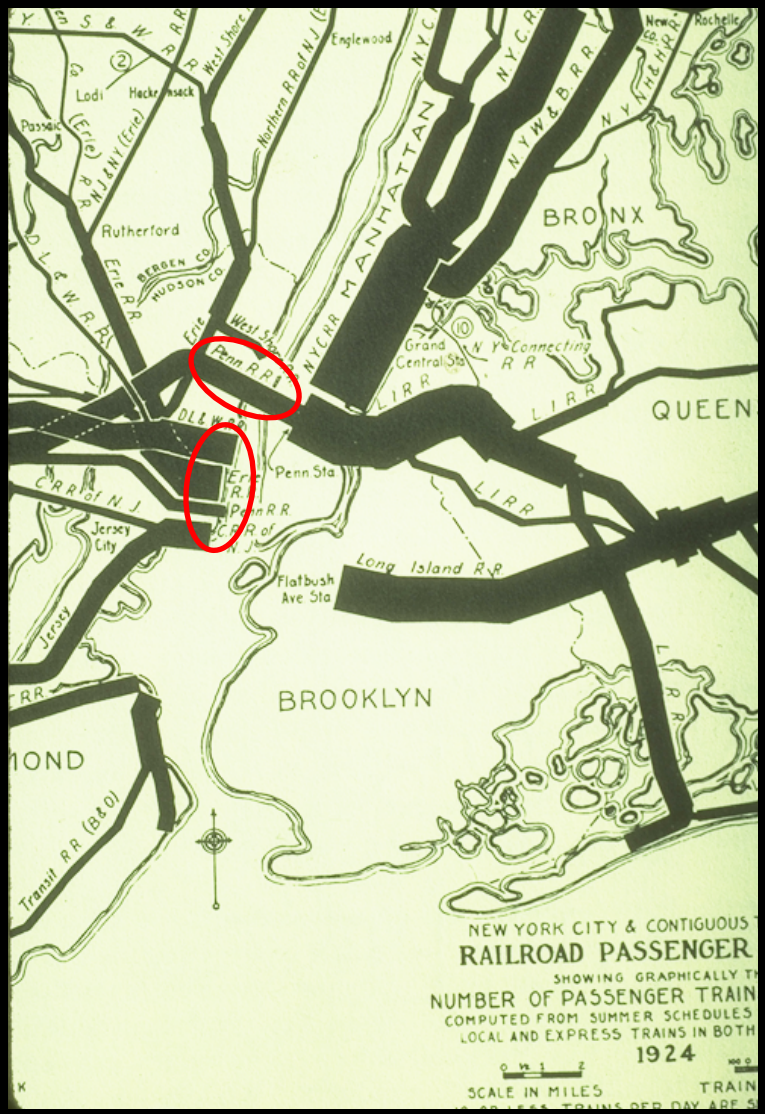
1921 - Port of New York Authority

US Constitution

(Article I, Section 10, Clause III)

"… no state shall, without the consent of Congress, enter into any agreement or compact with another state."



Port of New York Authority

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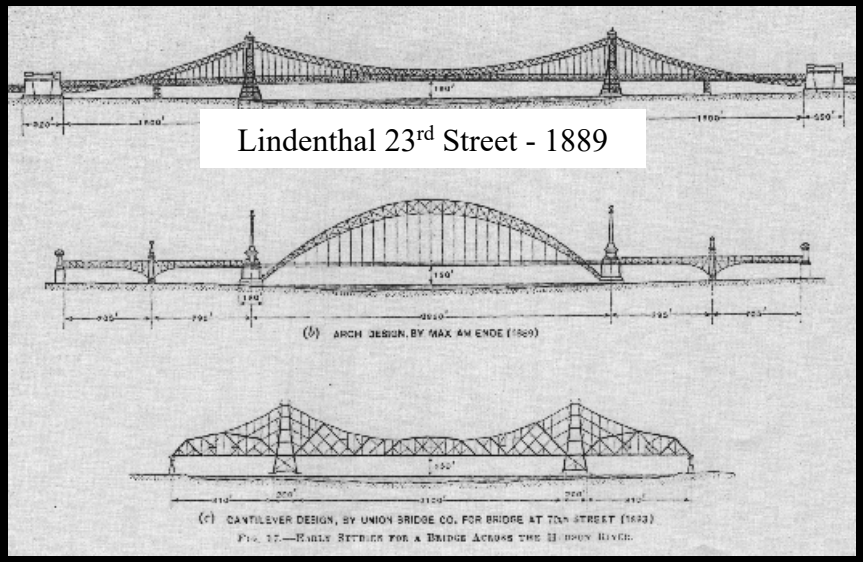
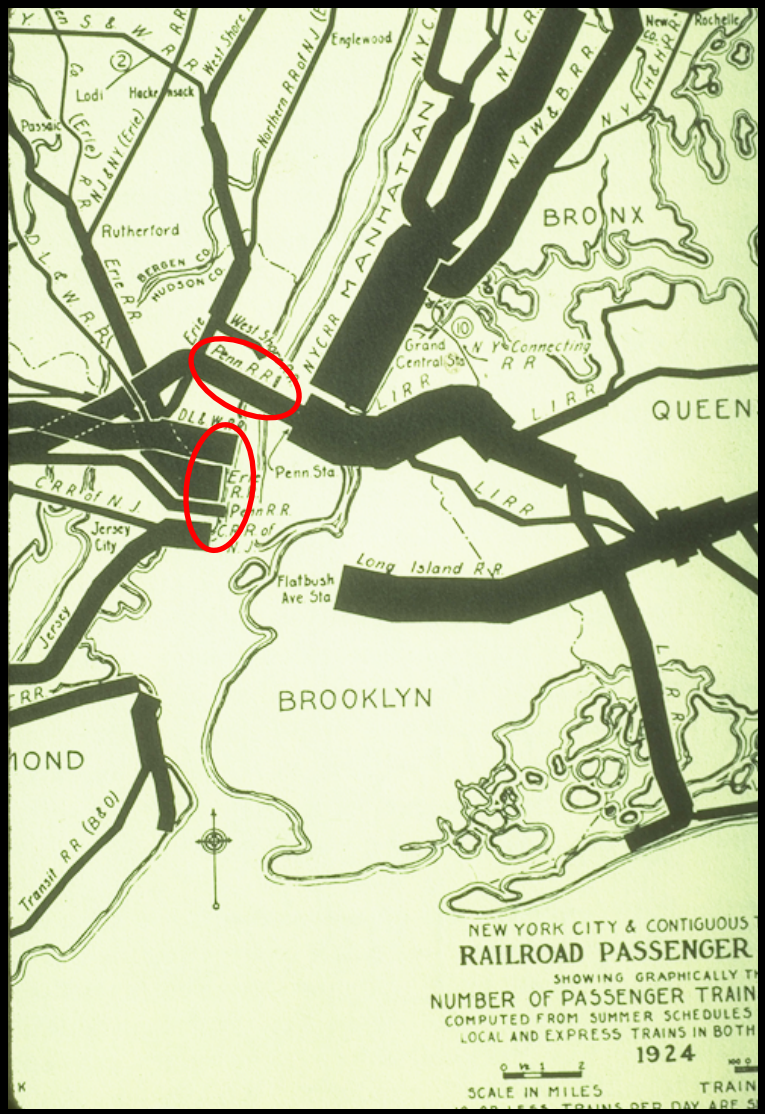
Proposals for the first Hudson River crossing connecting NY and NJ



Lindenthal 23rd Street - 1889



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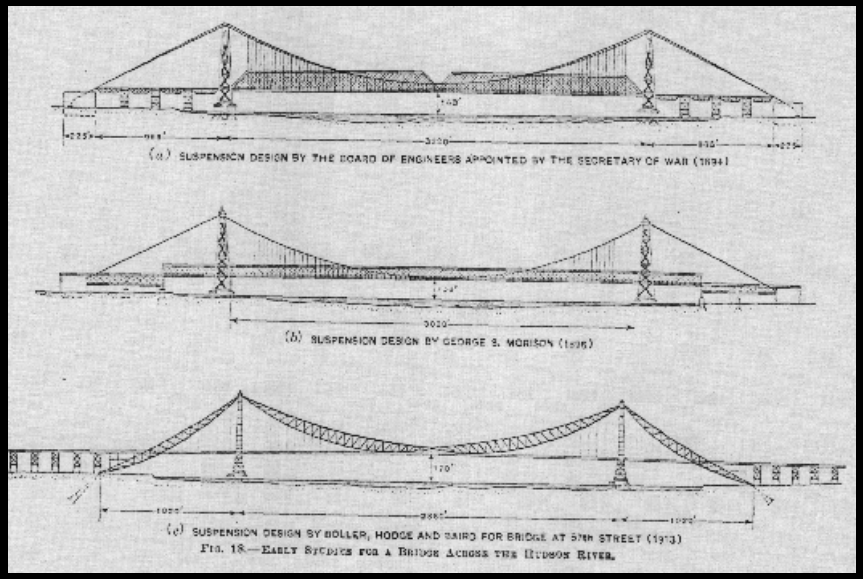
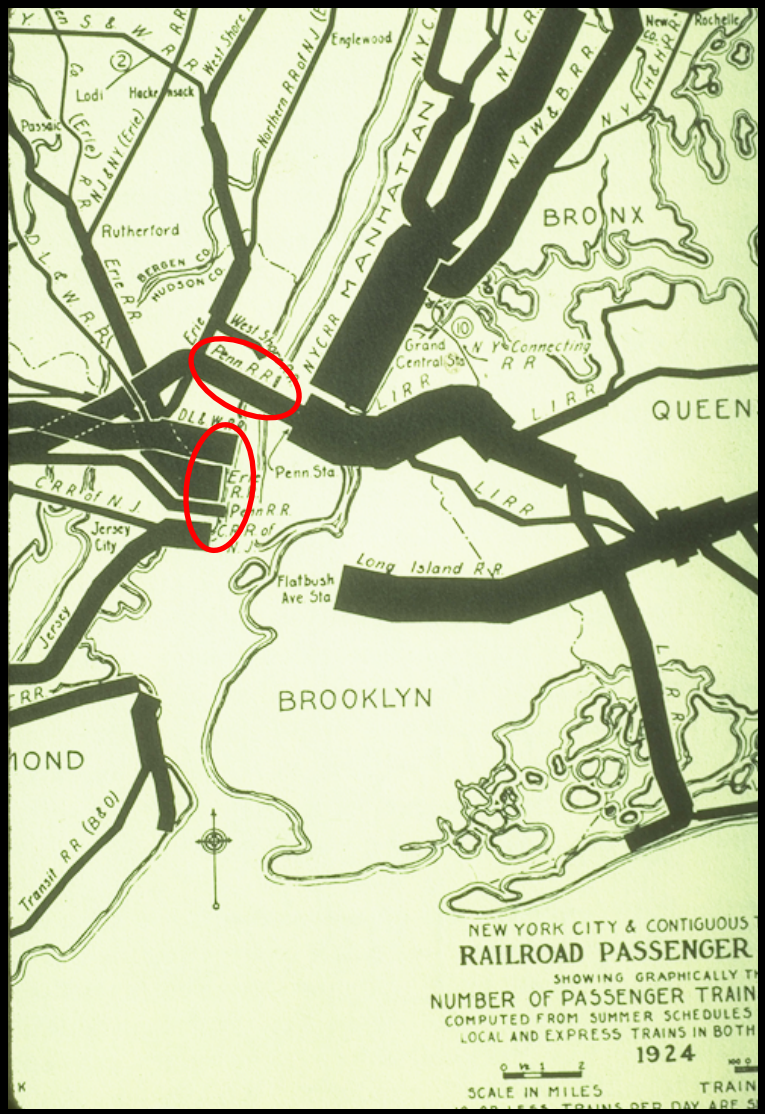
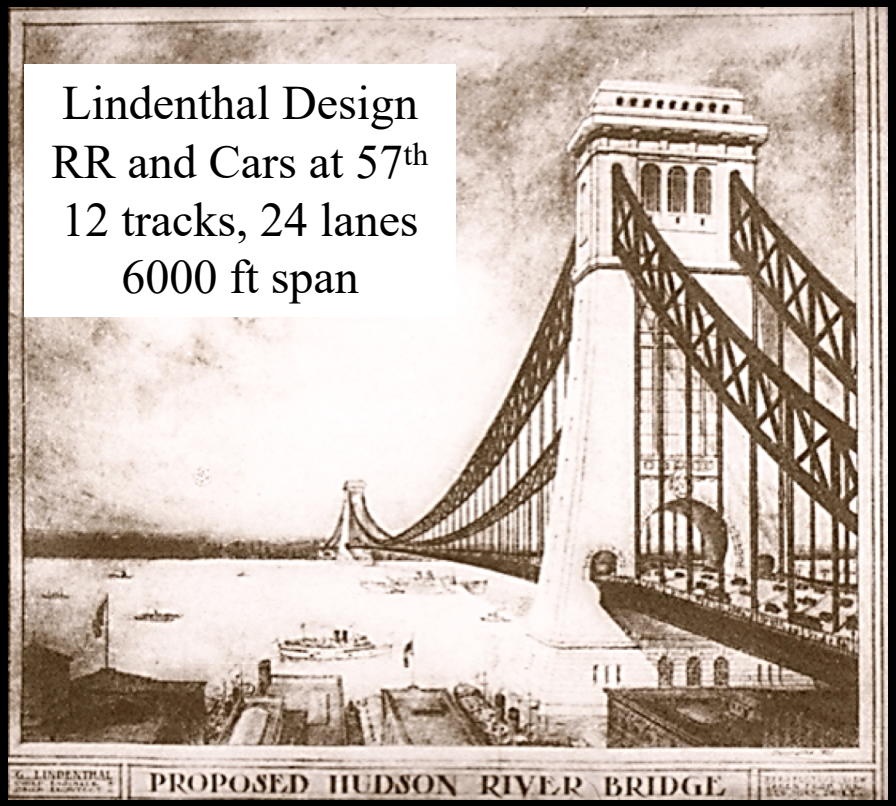
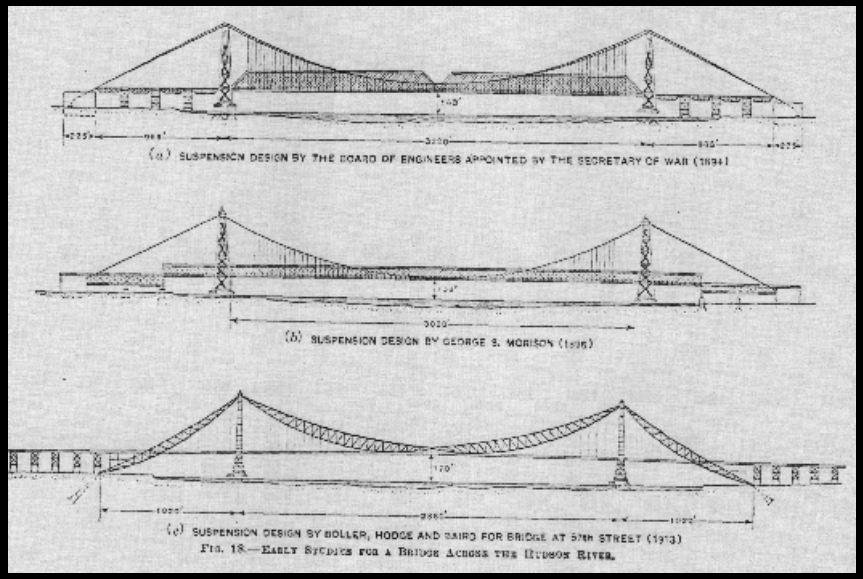
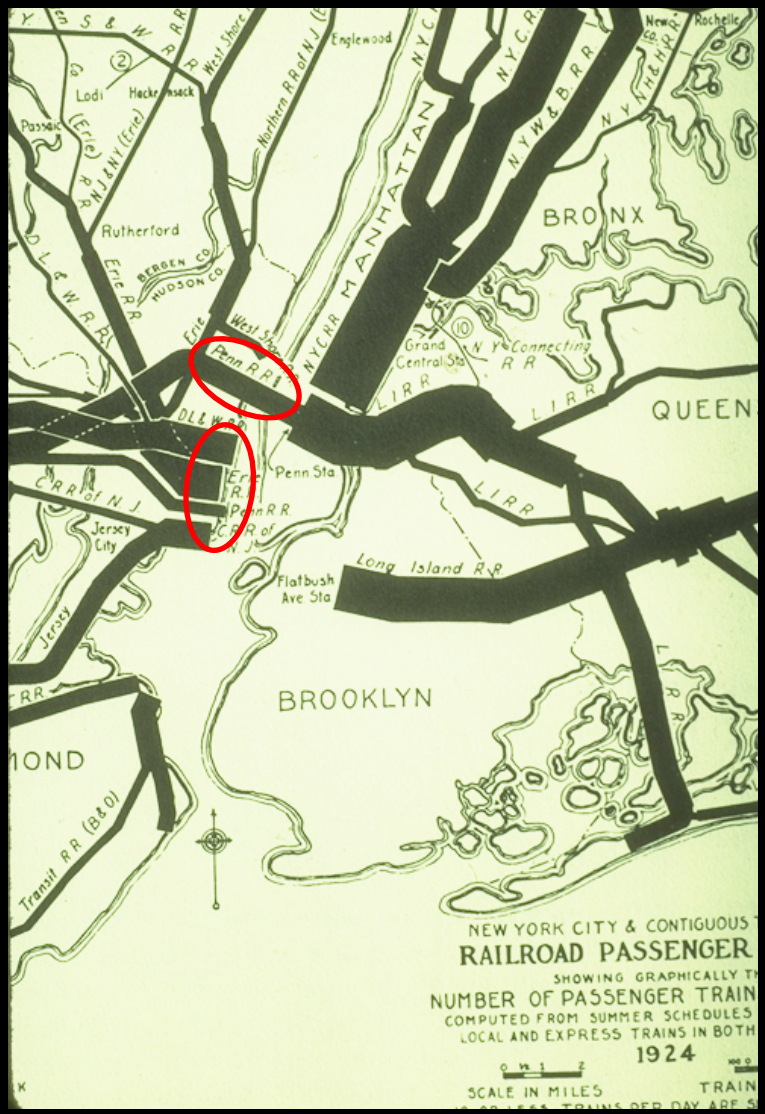




Lindenthal Design
RR and Cars at 57th
12 tracks, 24 lanes
6000 ft span







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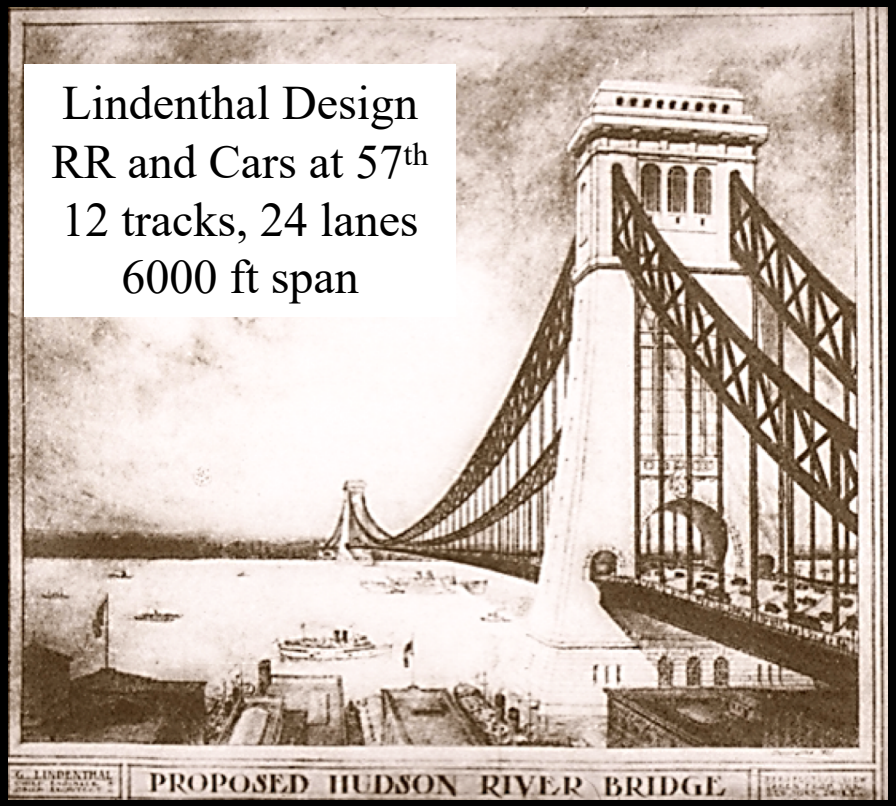


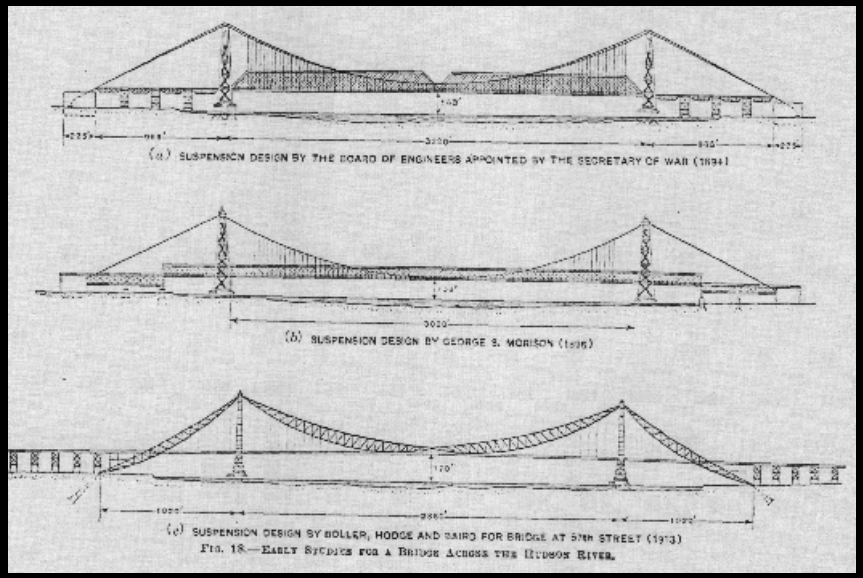
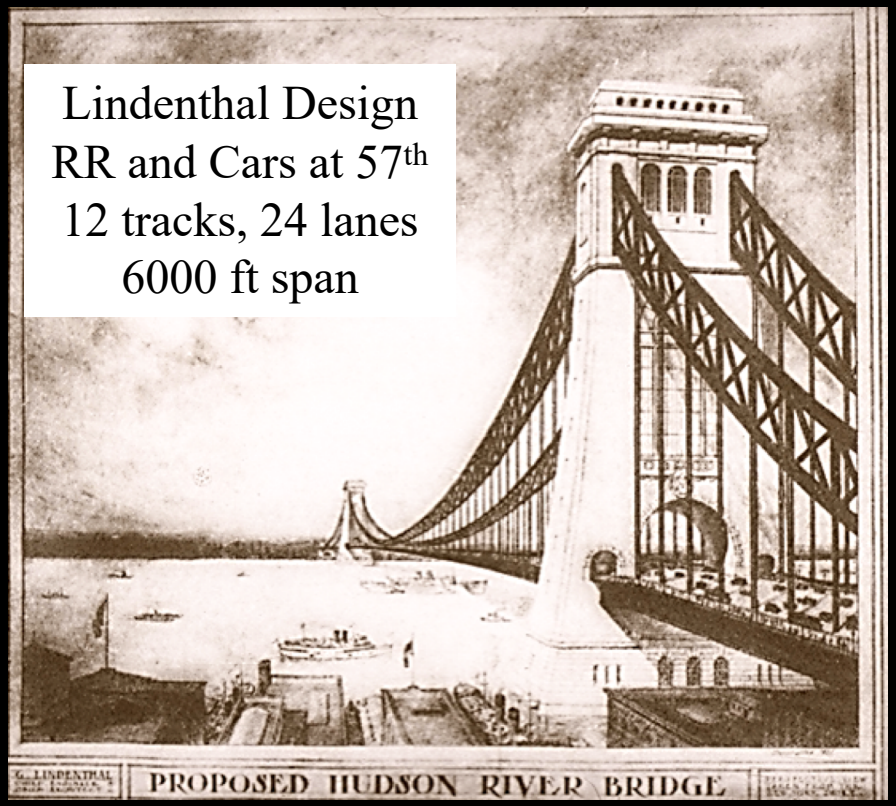
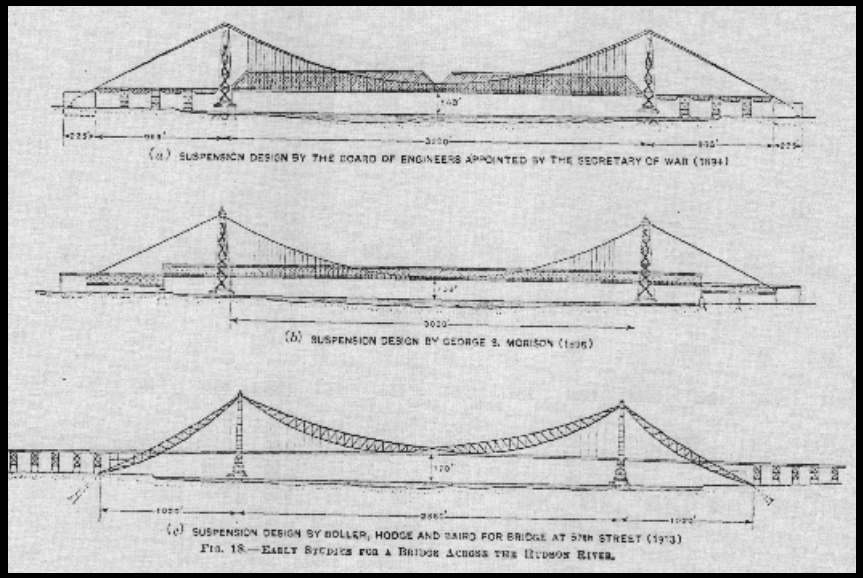


FIG. 18.—EARLY STUDIES FOR A BRIDGE ACROSS THE HUDSON RIVER.

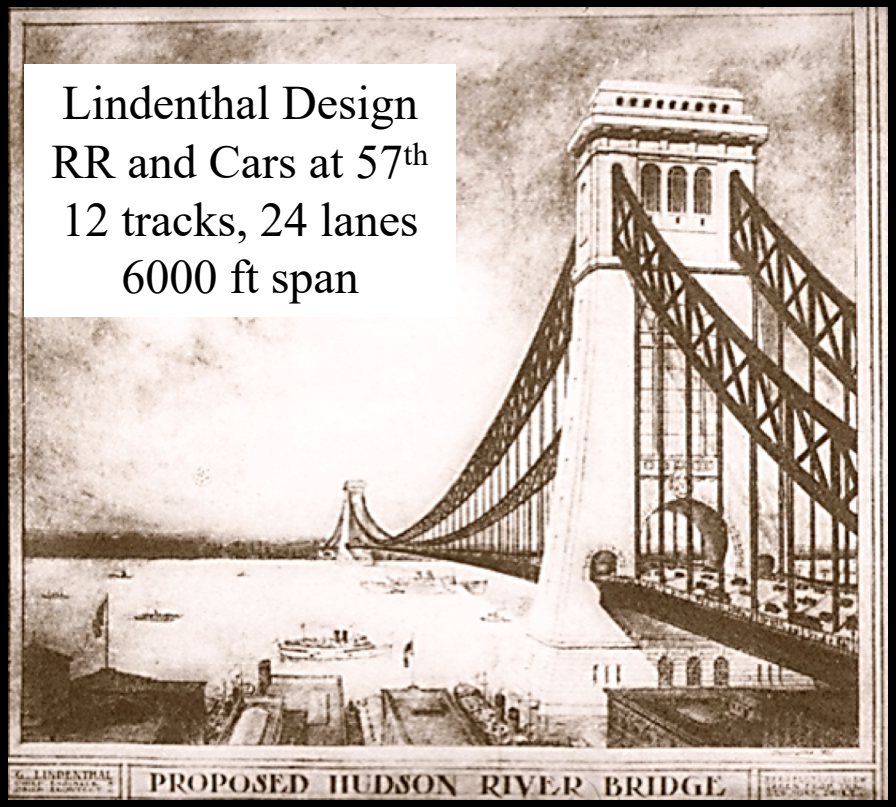
Lindenthal Design
RR and Cars at 57th
12 tracks, 24 lanes
6000 ft span



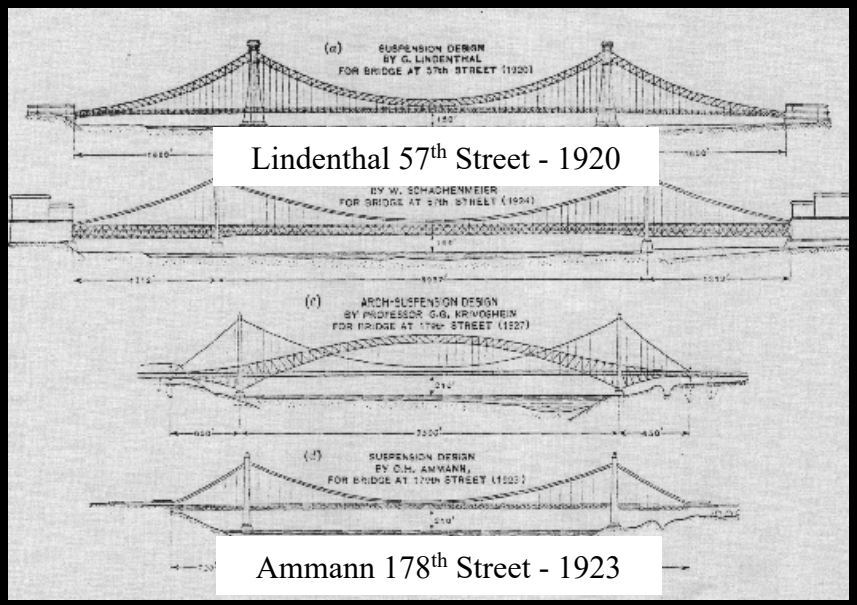


"… I … have been fighting against the unlimited ambition of a genius who is obsessed with illusions of grandeur."

Ammann writes to his mother - 1922



Lindenthal Design
RR and Cars at 57th
12 tracks, 24 lanes
6000 ft span



Lindenthal 57th Street - 1920

Ammann 178th Street - 1923

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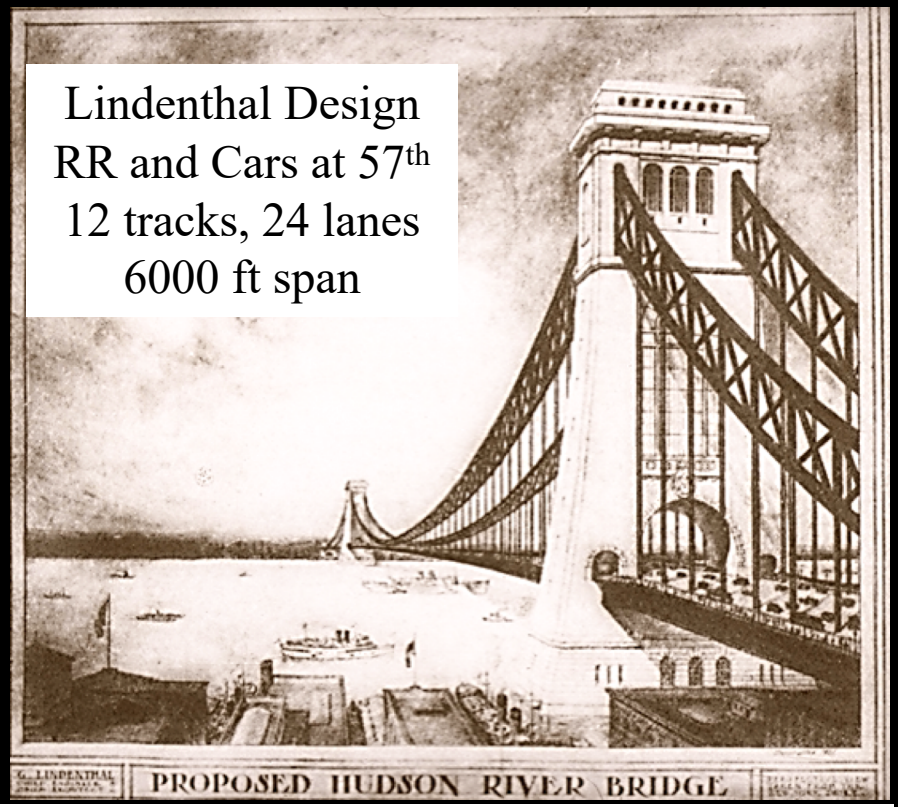

Lindenthal Design
RR and Cars at 57th
12 tracks, 24 lanes
6000 ft span

The George Washington Bridge
SYMBOLIC

Gustav Lindenthal -
inflexibility in the pioneer

George S. Silzer - the governor as
technological promoter

Othmar H. Ammann - the engineer
as entrepreneur and artist

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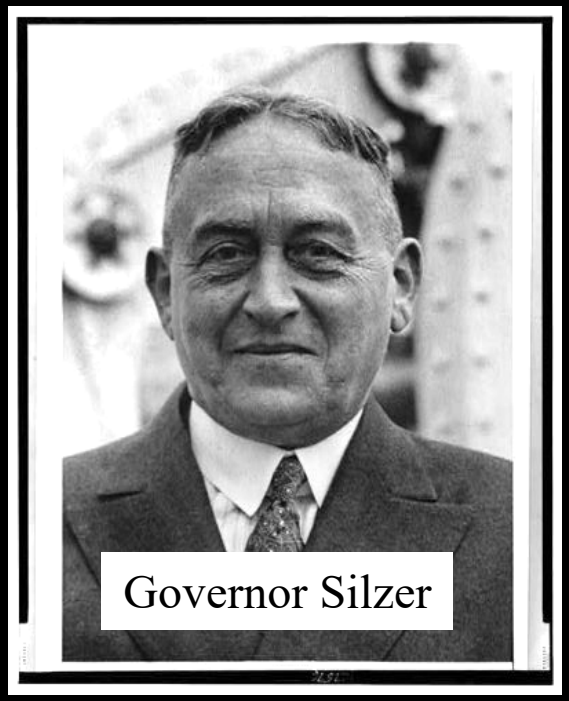
Governor Silzer

The George Washington Bridge
SYMBOLIC

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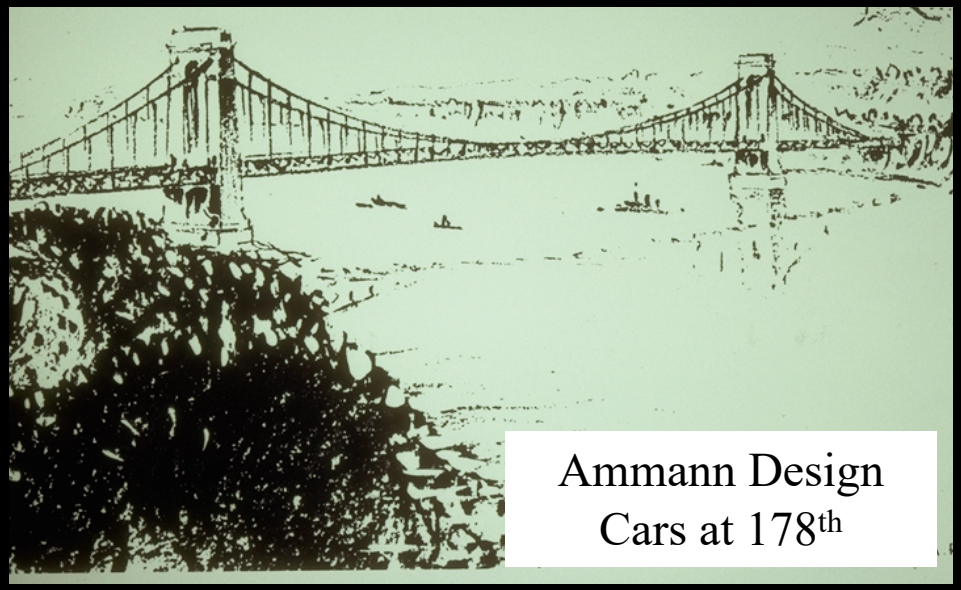


Ammann Design
Cars at 178th

The George Washington Bridge
SYMBOLIC

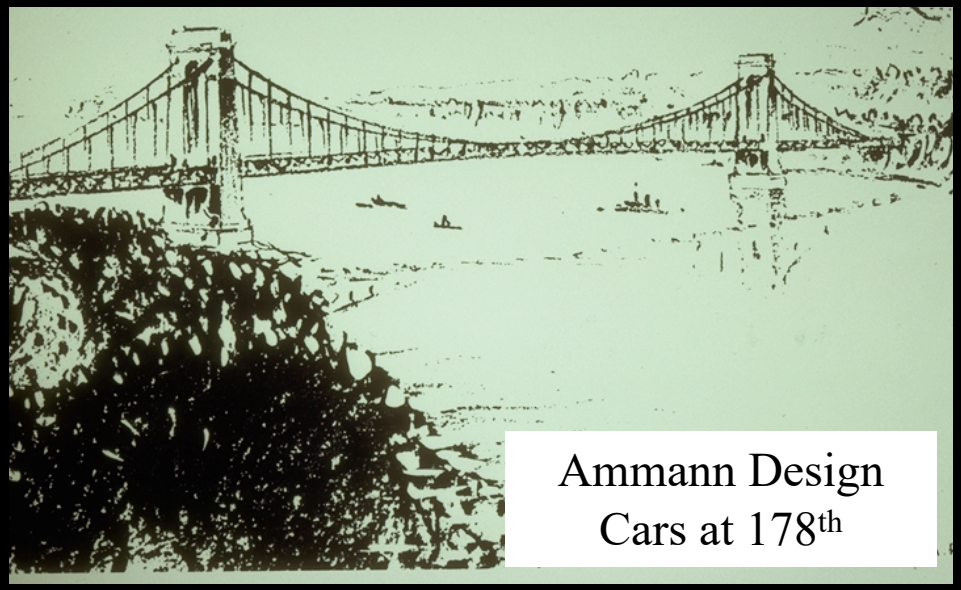
Gustav Lindenthal - inflexibility in the pioneer

George S. Silzer - the governor as technological promoter

Othmar H. Ammann - the engineer as entrepreneur and artist

"… a great bridge in a great city … should … be a work of art to which Science lends its aid."

Othmar Ammann



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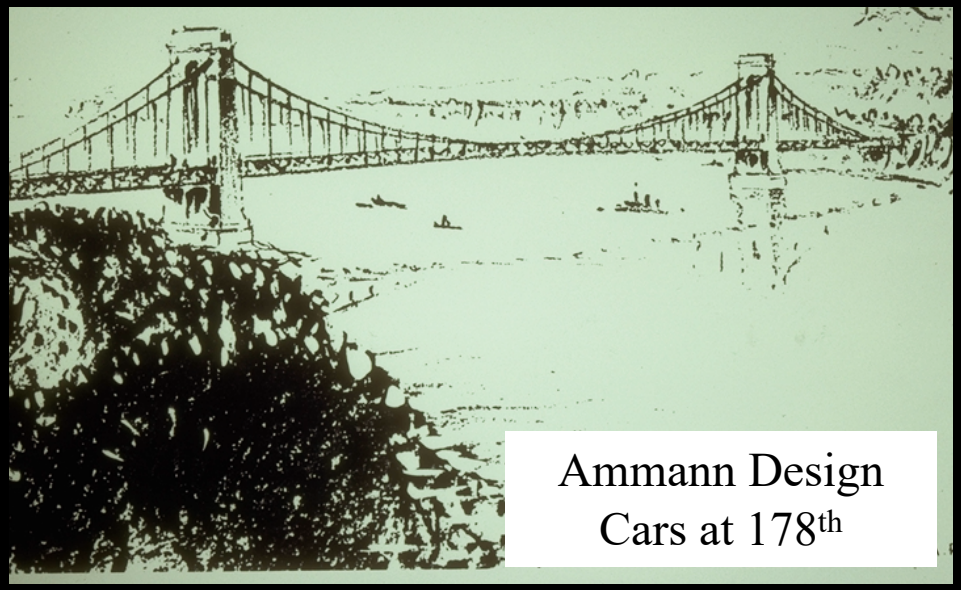

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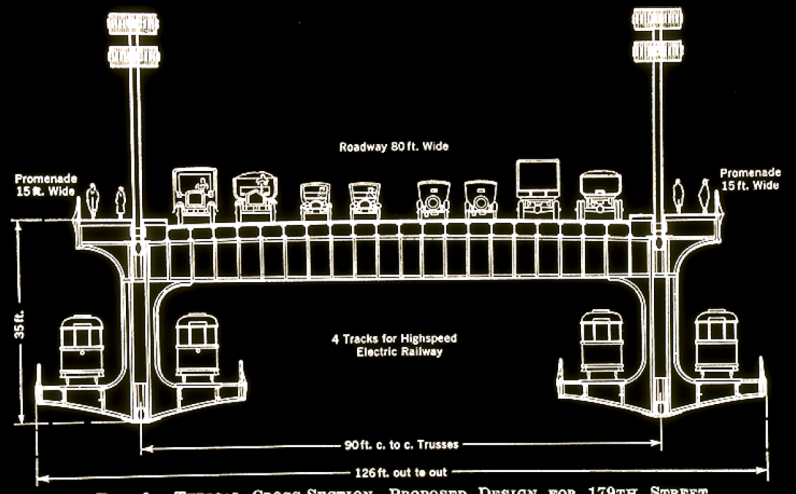
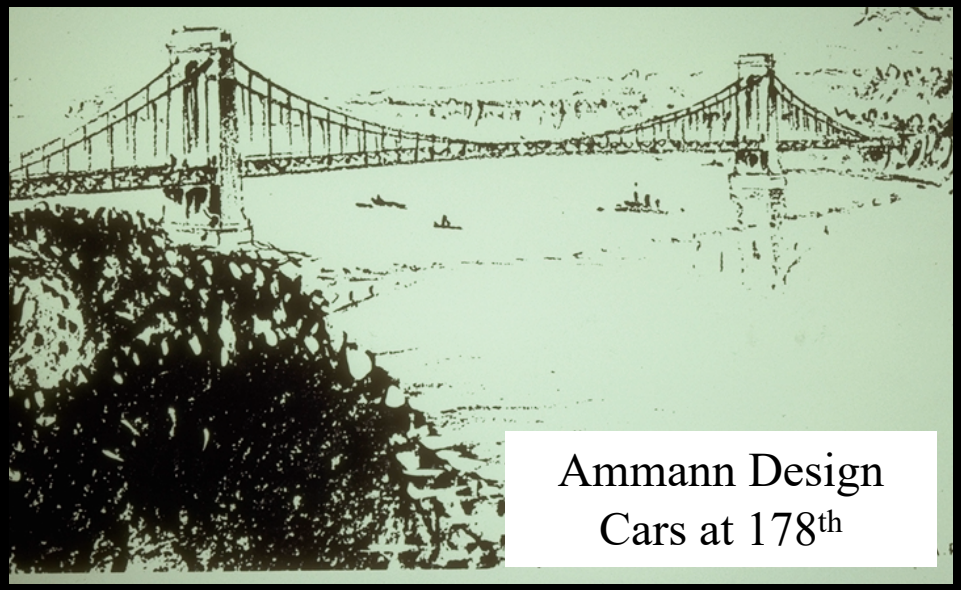


FIG. 6.—TYPICAL CROSS-SECTION, PROPOSED DESIGN FOR 179TH STREET SUSPENSION BRIDGE



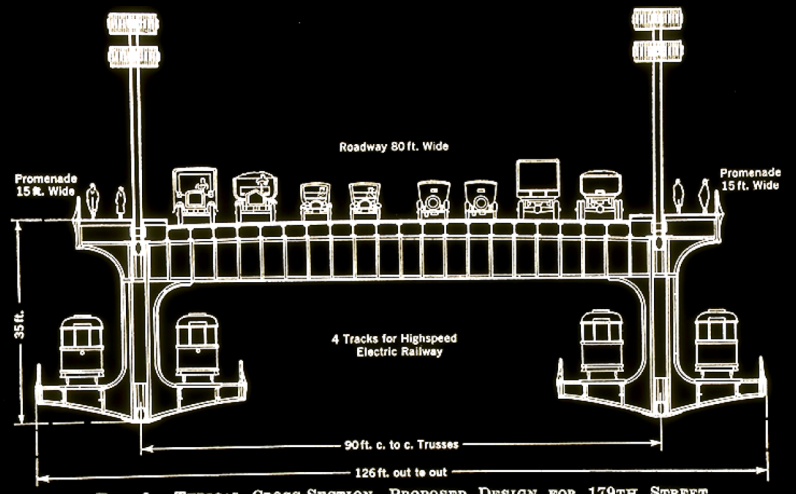
Ammann Design
Cars at 178th

The George Washington Bridge
SCIENTIFIC

dead weight - heaviest bridge ever

traffic weight - low probability of full truck loading

wind force - neglect of vertical motion due to horizontal loading



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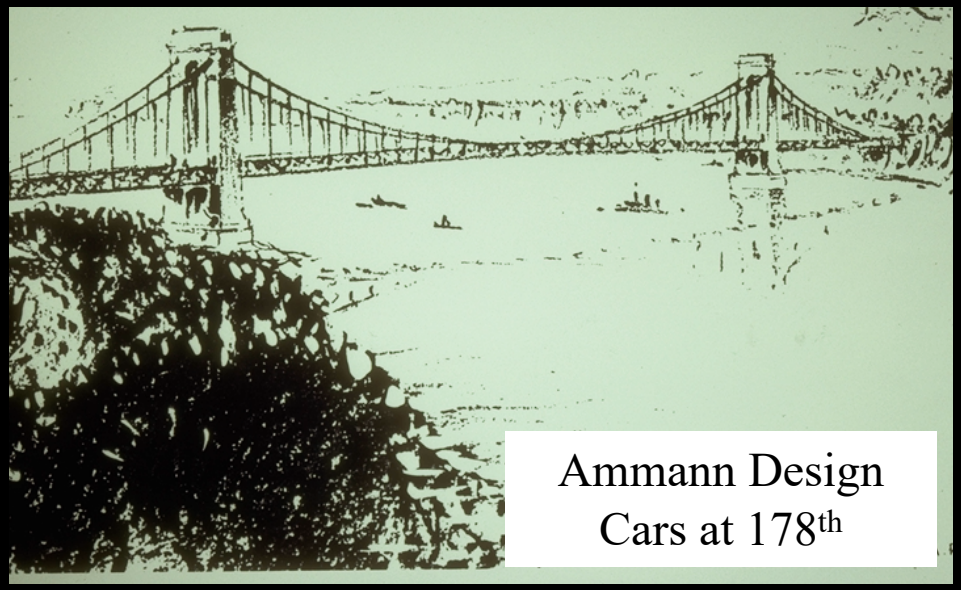

Ammann Design
Cars at 178th

DEFLECTION THEORY

The **heavier the span weight**, the greater the cable tension: $\mathbf{H = \frac{qL^2}{8d}}$

The **greater the cable tension**, the stiffer the span: **STIFFNESS OF TAUT CABLE**

The **stiffer the span**, the less need for deck trusses: **ELEGANCE OF THIN DESIGN**

The George Washington Bridge
SCIENTIFIC

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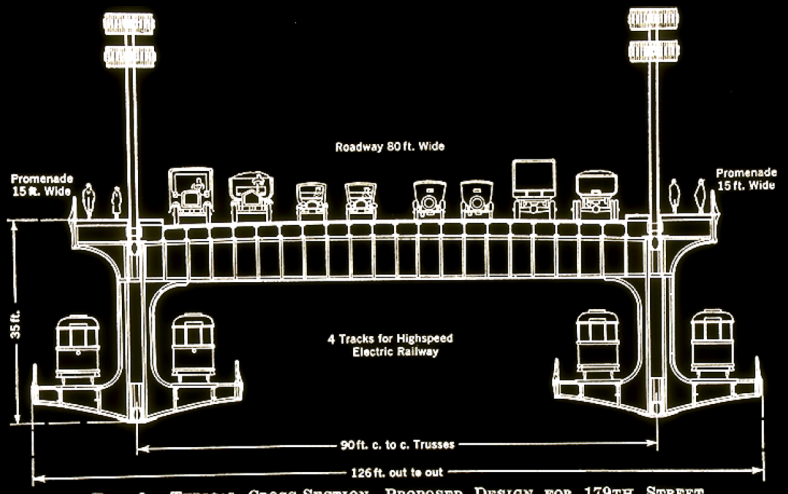

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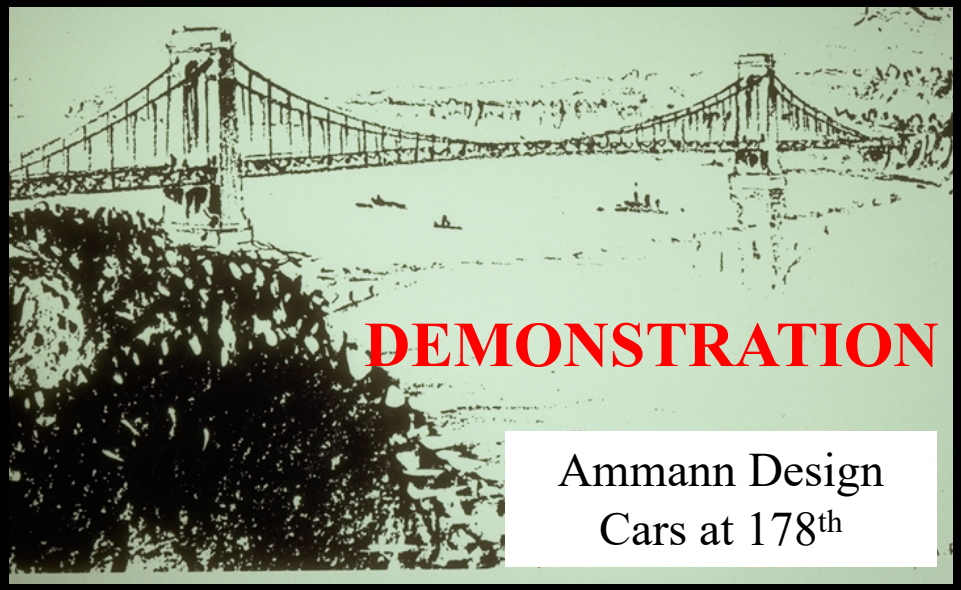

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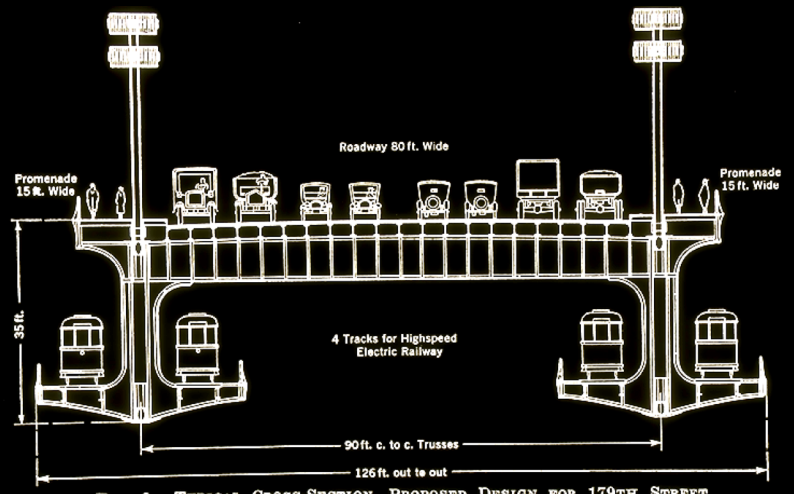

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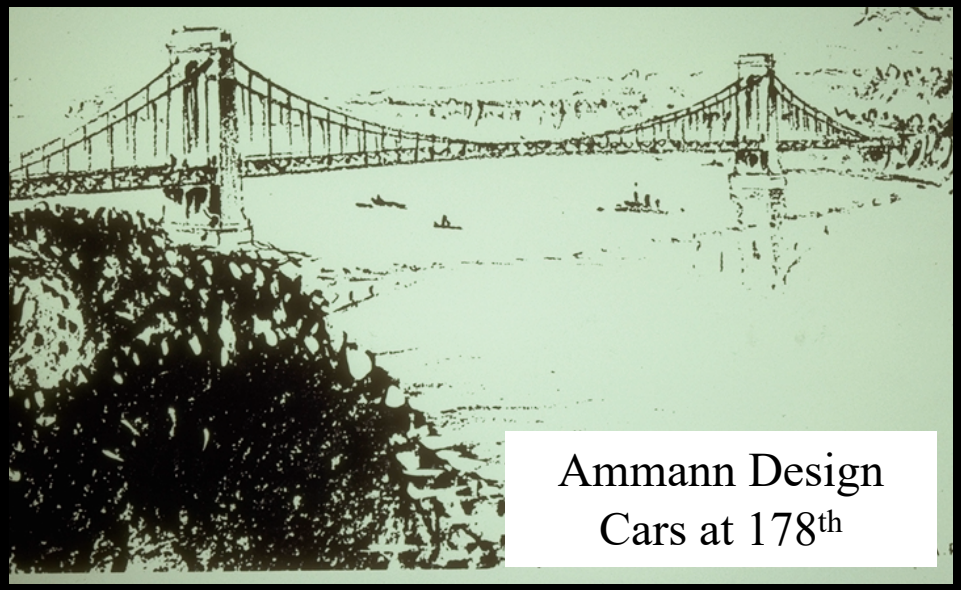

Ammann Design
Cars at 178th

Loaded Length Factor:

$$K = 0.2 + [160 / (200 + L)]$$

Number of Lanes Factor:

$$C = 0.5 + [2 / (n + 3)]$$

The George Washington Bridge
SCIENTIFIC

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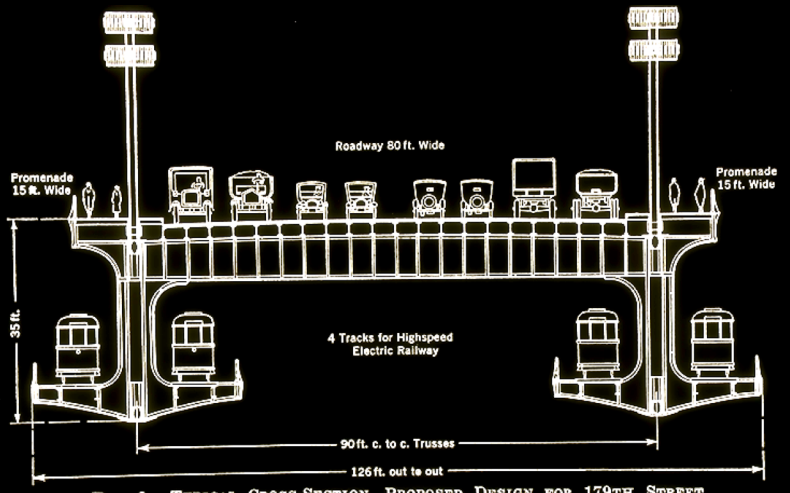

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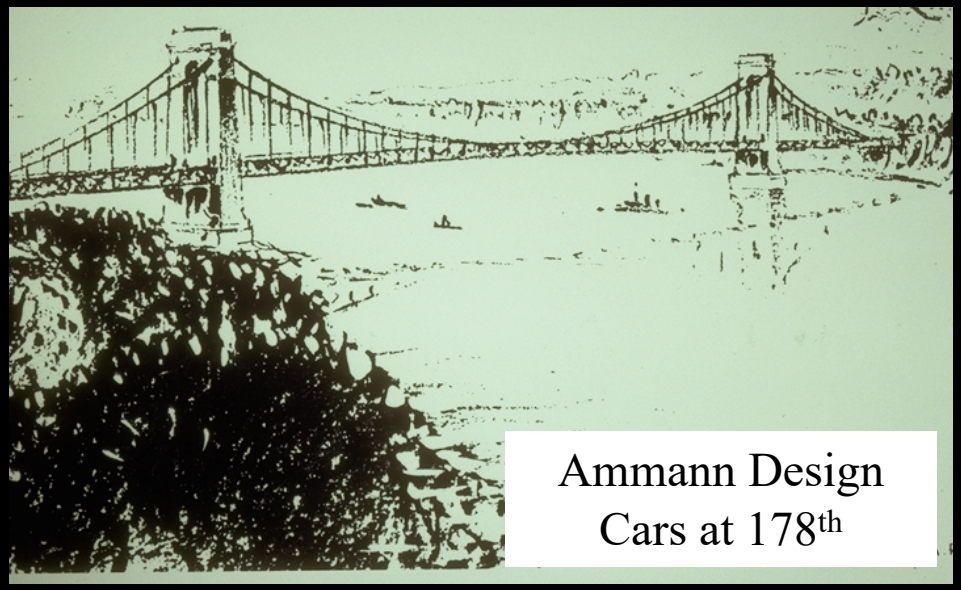


Ammann Design
Cars at 178th

Minimum (L = 3500) $K=0.2+(160/3700)\approx0.25$

Minimum (n = 8) $C=0.5+(2/11)=0.682$

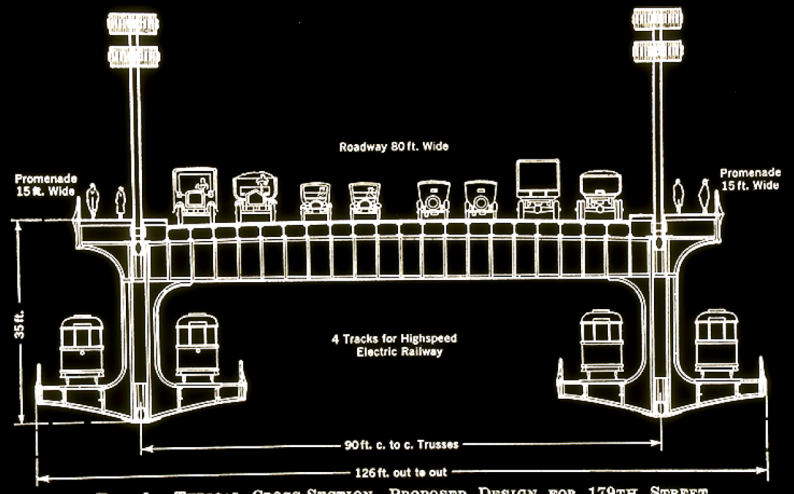
$C * K = 0.25 * 0.682 = 0.17$

The George Washington Bridge
SCIENTIFIC

dead weight - heaviest bridge ever

traffic weight - low probability of full truck loading

wind force - neglect of vertical motion due to horizontal loading



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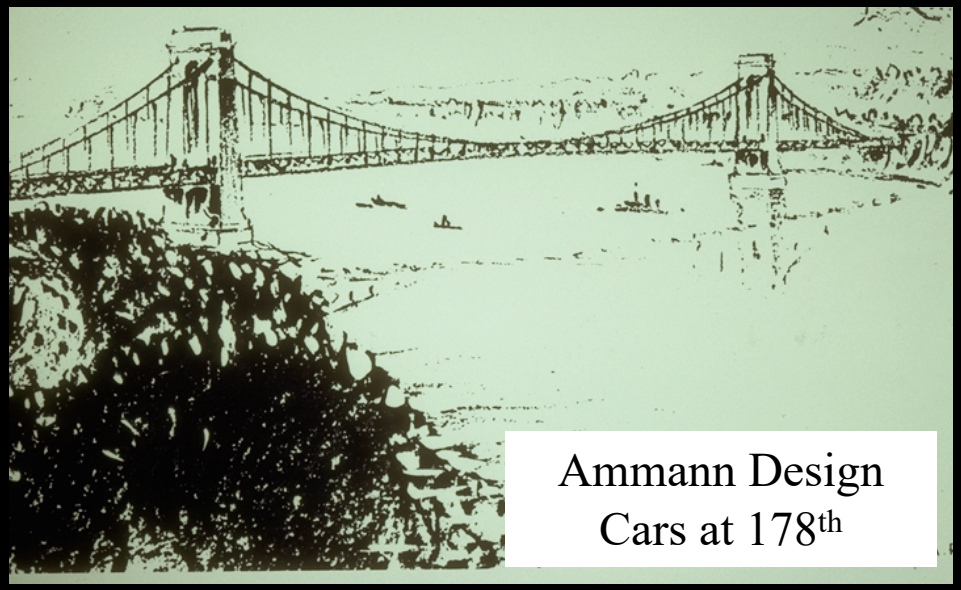

Ammann Design
Cars at 178th

$$q_L = 0.17 \times 46{,}000$$
$$= 7820 \text{ lb/ft}$$

The George Washington Bridge
SCIENTIFIC

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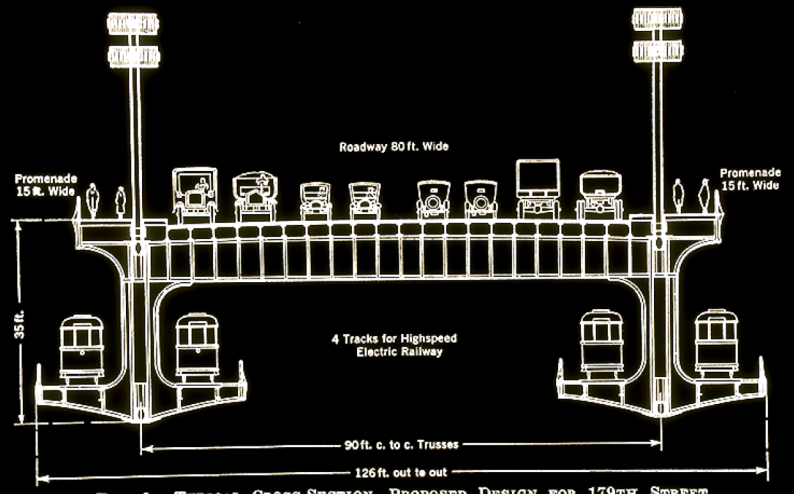
traffic weight - low probability of full truck loading

wind force - neglect of vertical motion due to horizontal loading



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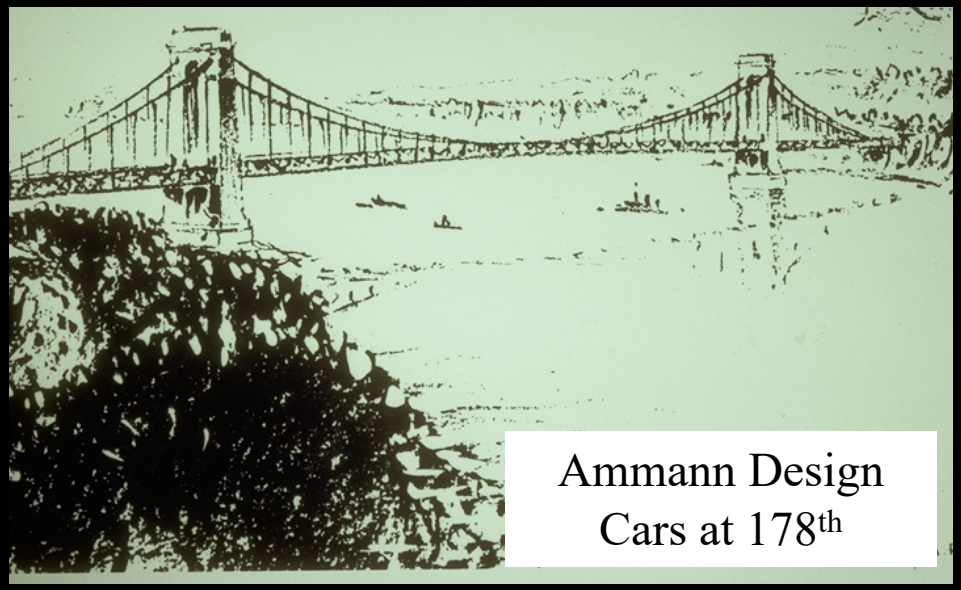


Ammann Design
Cars at 178th

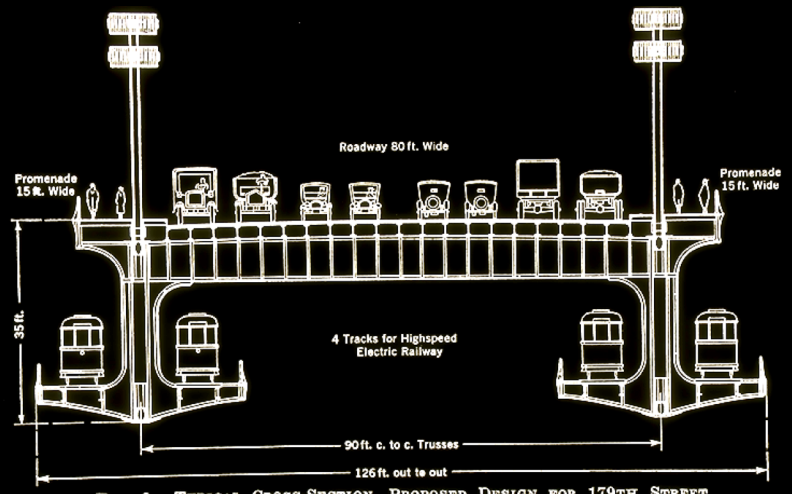
Tacoma Narrows Bridge – 1940
Deflection theory error – ignores wind load

The George Washington Bridge
SCIENTIFIC

dead weight - heaviest bridge ever

traffic weight - low probability of full truck loading

wind force - neglect of vertical motion due to horizontal loading



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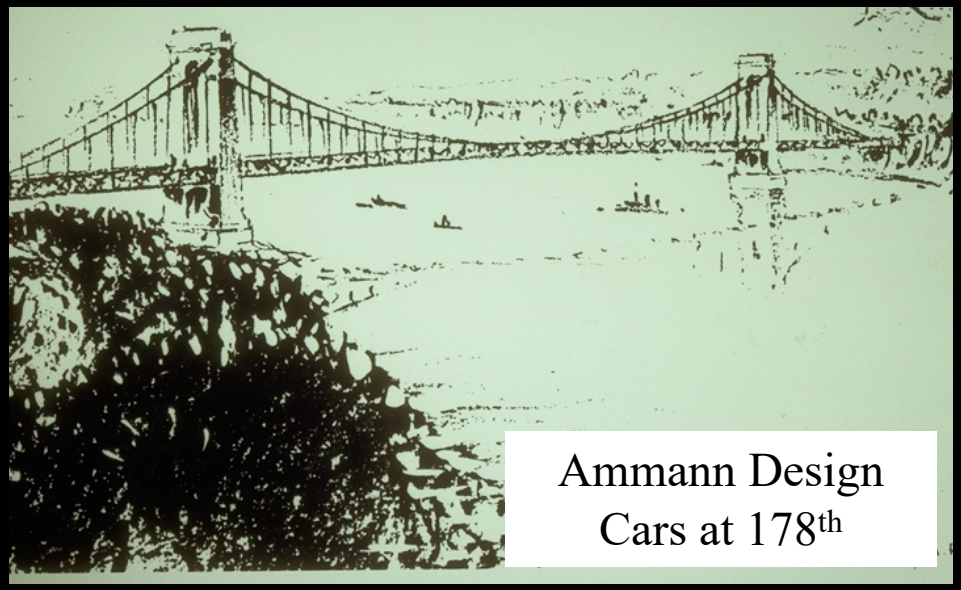

Ammann Design
Cars at 178th

Manhattan Bridge – 1909
First to use Deflection Theory

The George Washington Bridge
SCIENTIFIC

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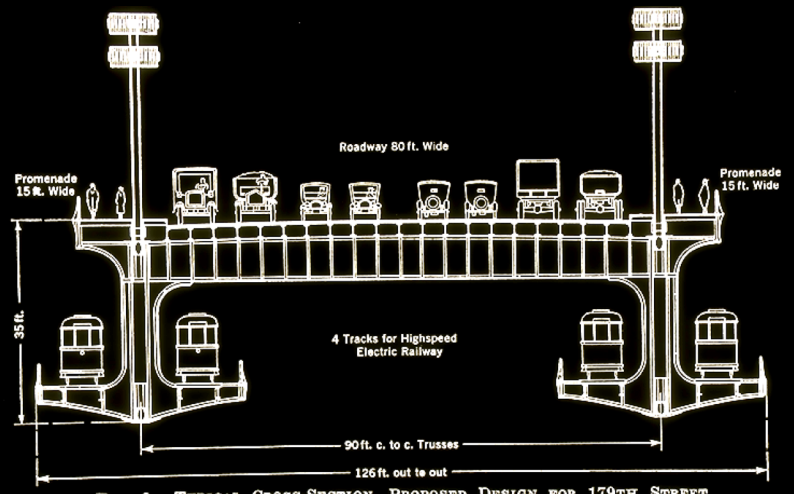
wind force - neglect of vertical motion due to horizontal loading



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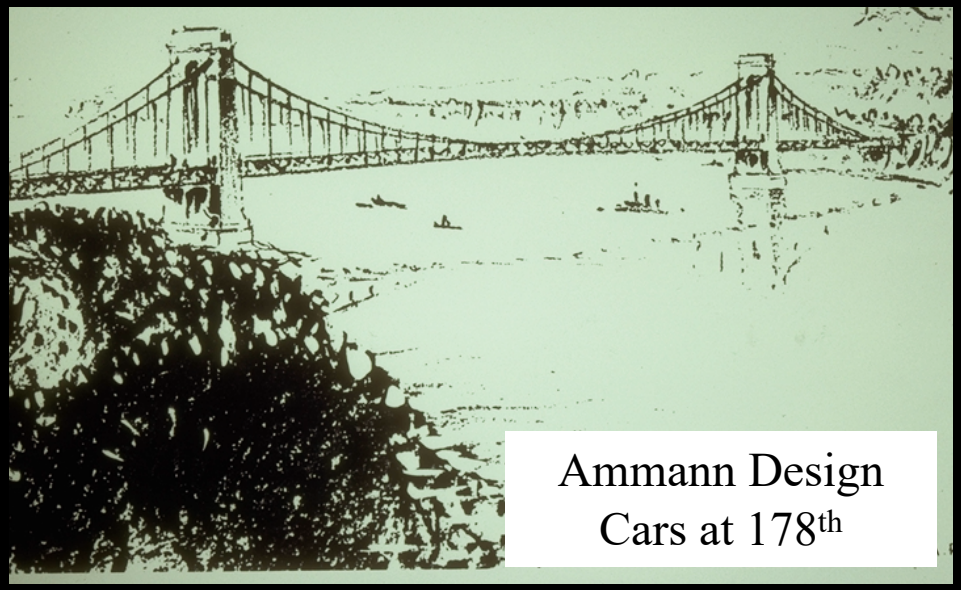

Ammann Design
Cars at 178th

Carmody Report

Ammann, Von Karman, and Woodruff

(1) 1940 Narrows Bridge failed because of "excessive flexibility;"

(2) Solid plate deck acted like a wing, creating "drag" and "lift;"

(3) Suspension bridge designs should be tested in a wind tunnel.

The George Washington Bridge
SCIENTIFIC

dead weight - heaviest bridge ever

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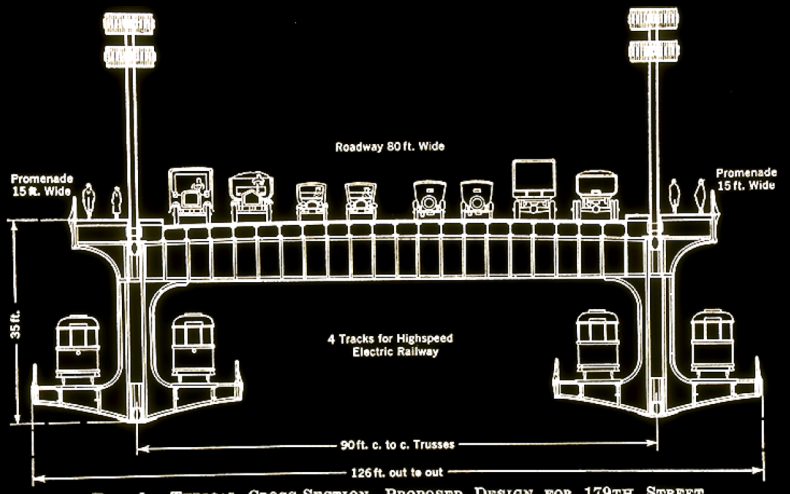
wind force - neglect of vertical motion due to horizontal loading



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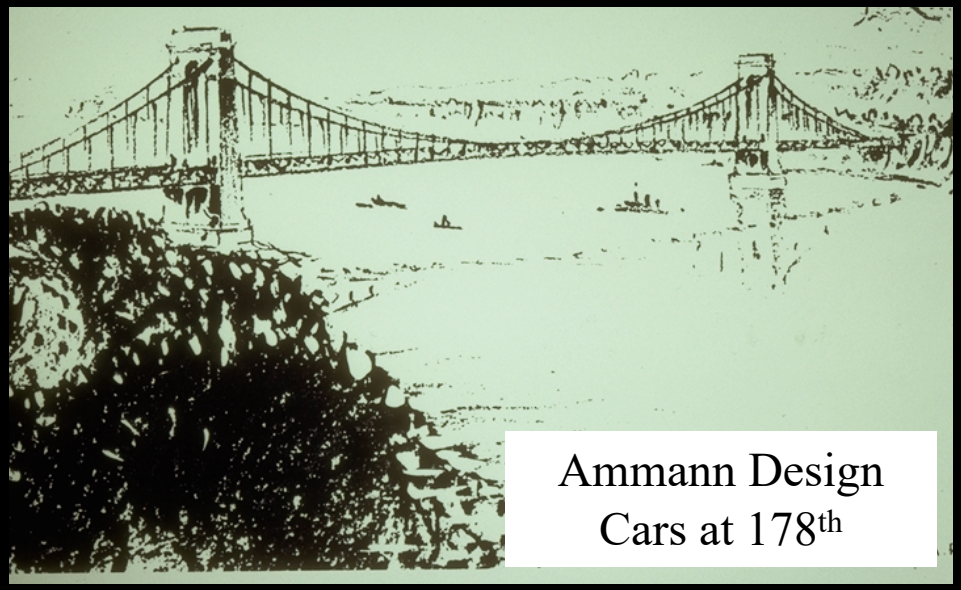

Ammann Design
Cars at 178th

Tacoma Narrows Replacement – 1950
Stiffer Deck

The George Washington Bridge
SCIENTIFIC

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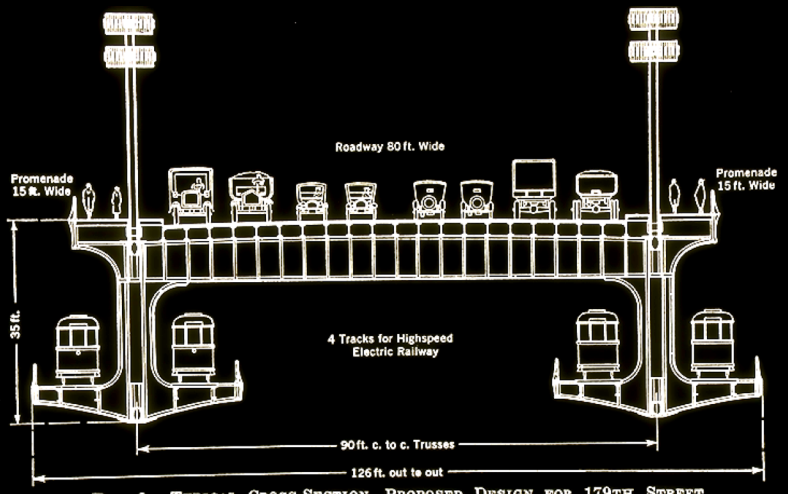

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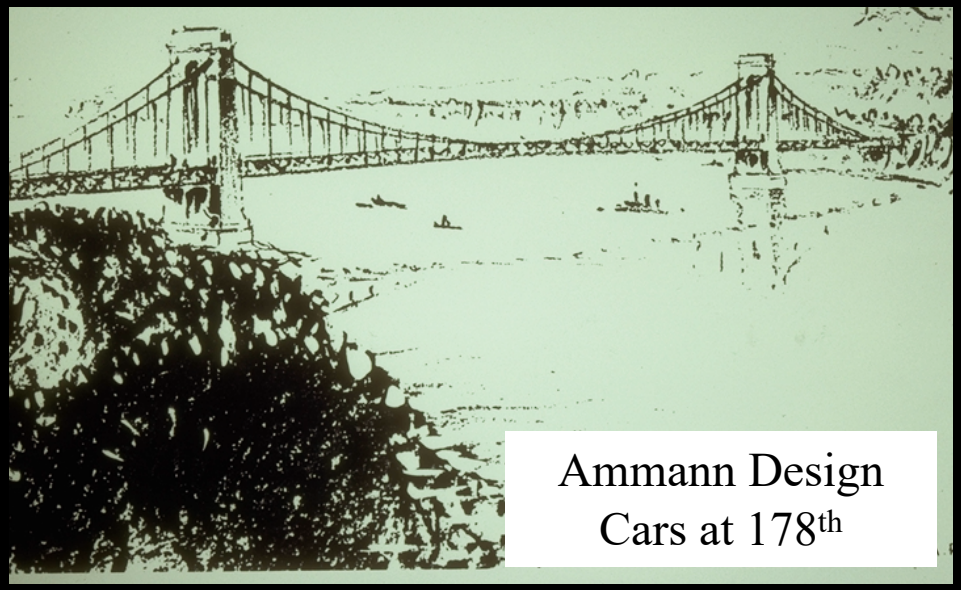


Ammann Design
Cars at 178th

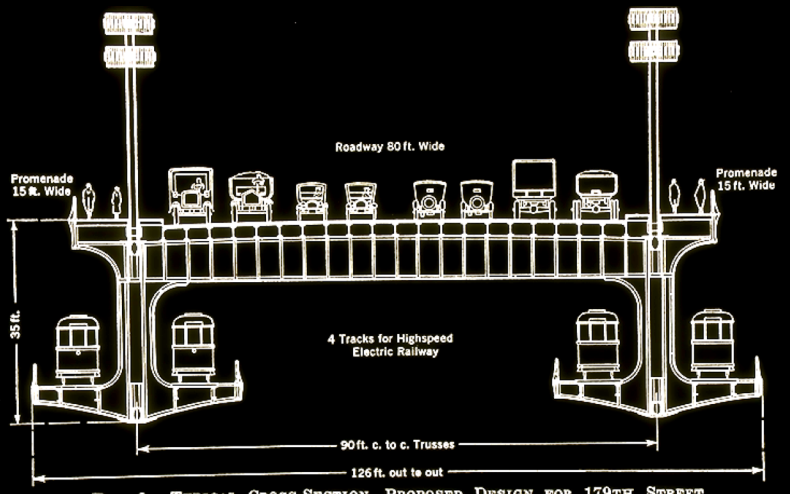
Bronx Whitestone addition – 2003
Wing-like ‘fairing’ reduces flutter

The George Washington Bridge
SCIENTIFIC

dead weight - heaviest bridge ever

traffic weight - low probability of full truck loading

wind force - neglect of vertical motion due to horizontal loading



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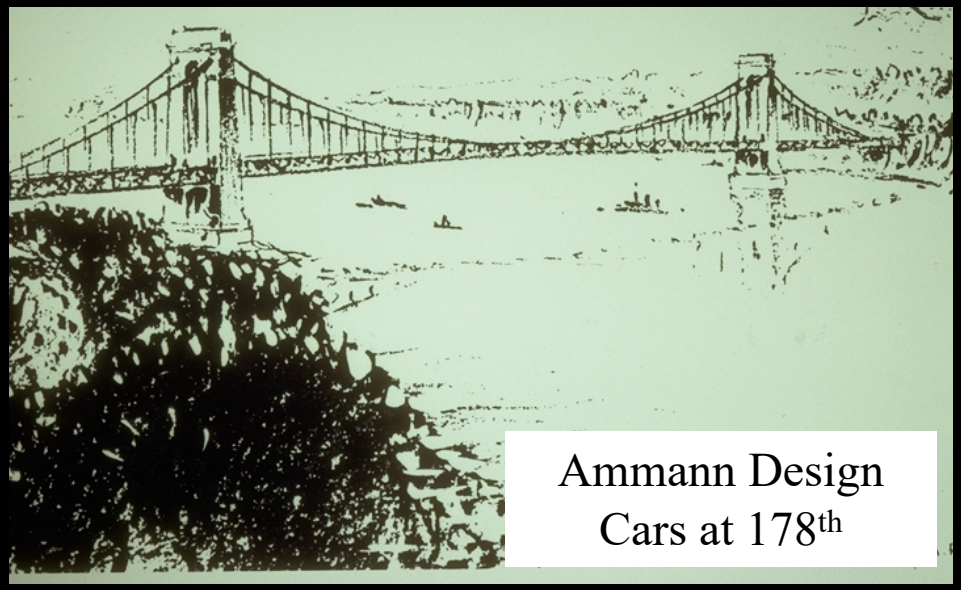

Ammann Design
Cars at 178th

The George Washington Bridge
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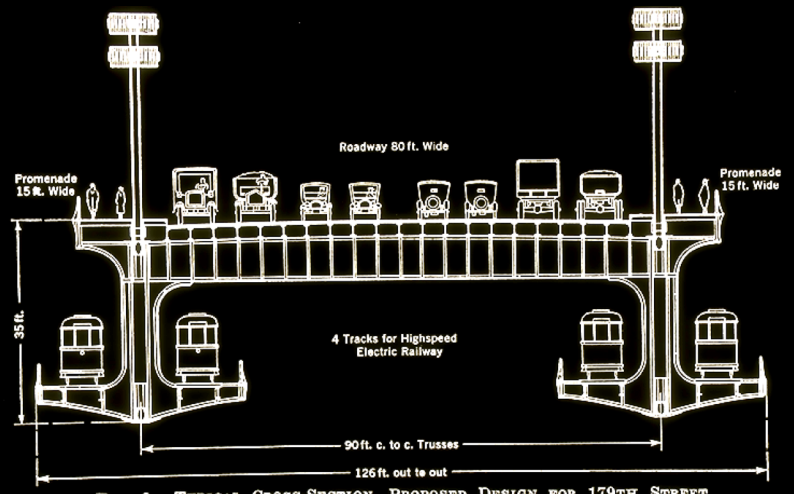

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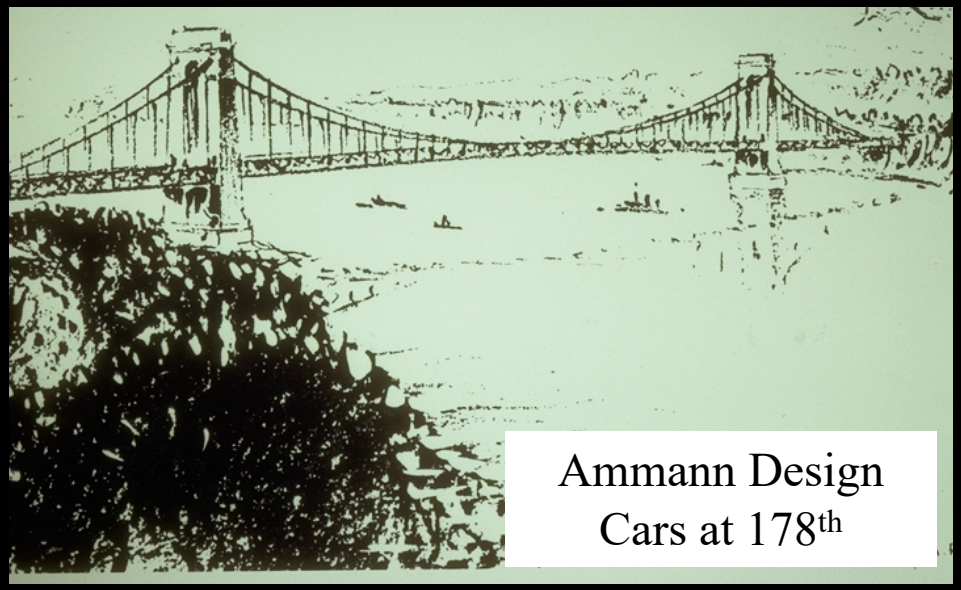
Ammann



Ammann Design Cars at 178th

The George Washington Bridge
SCIENTIFIC

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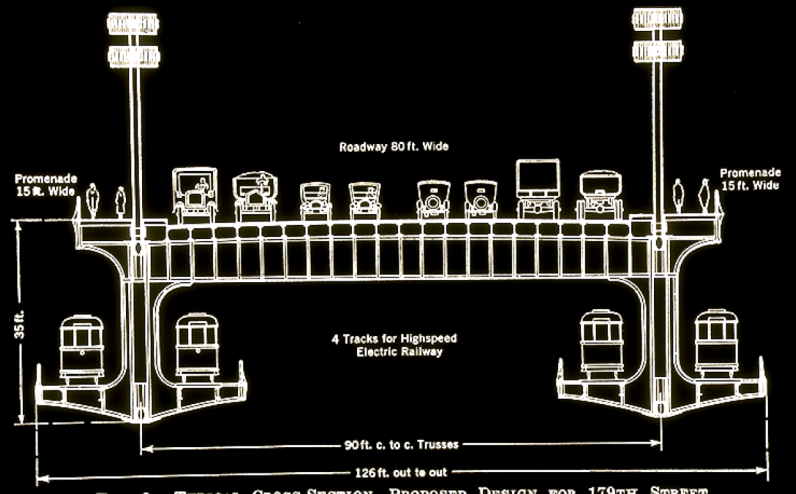

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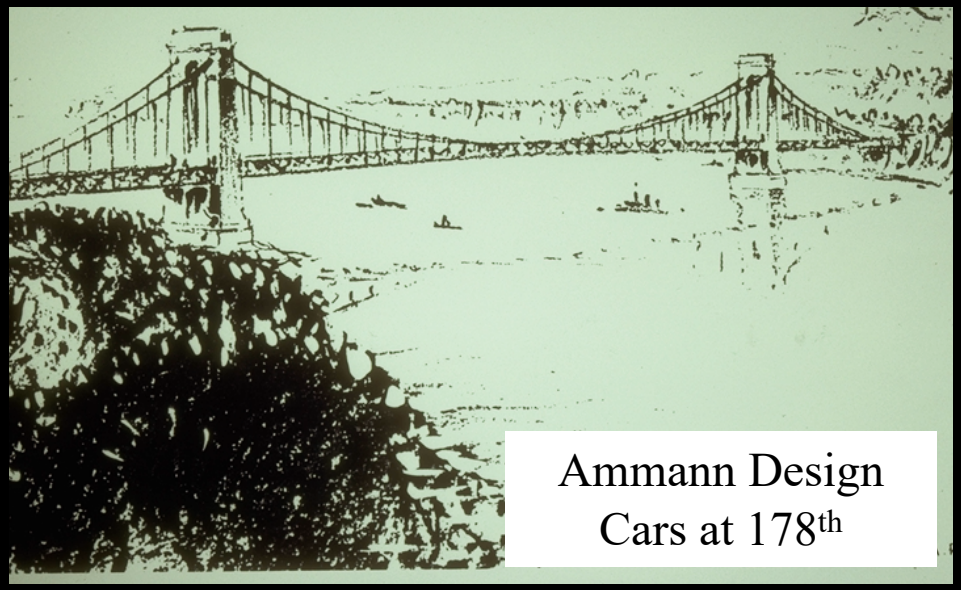


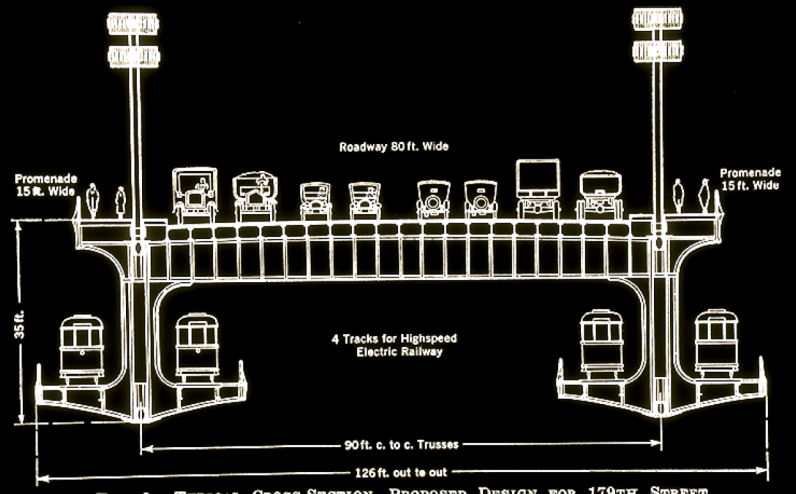
Ammann Design
Cars at 178th

The George Washington Bridge
SOCIAL

a new political instrument –
a bi-state agency

the necessity of low cost -
light deck, reduced traffic load

transformation of communities –
trains to cars, rural to suburban



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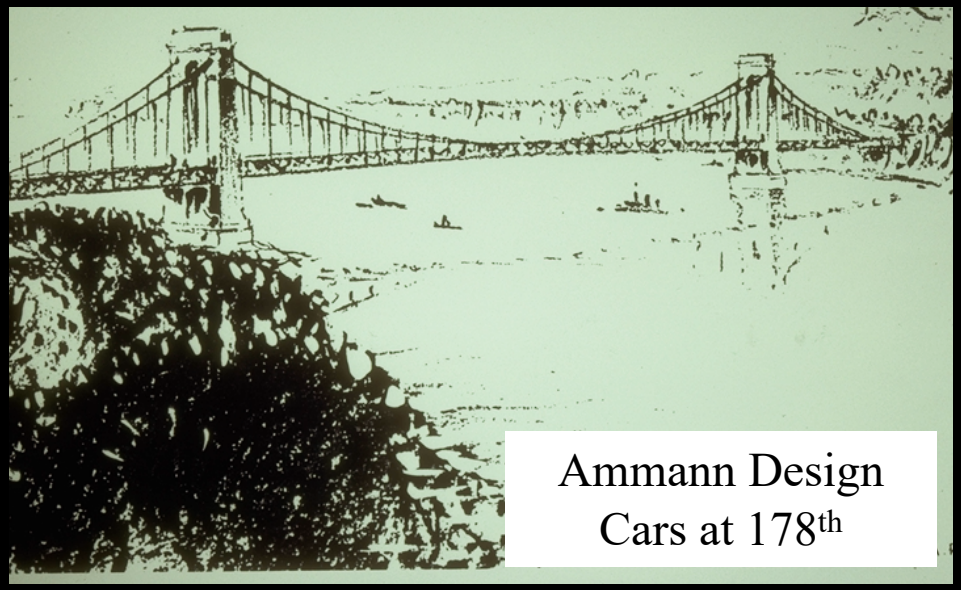

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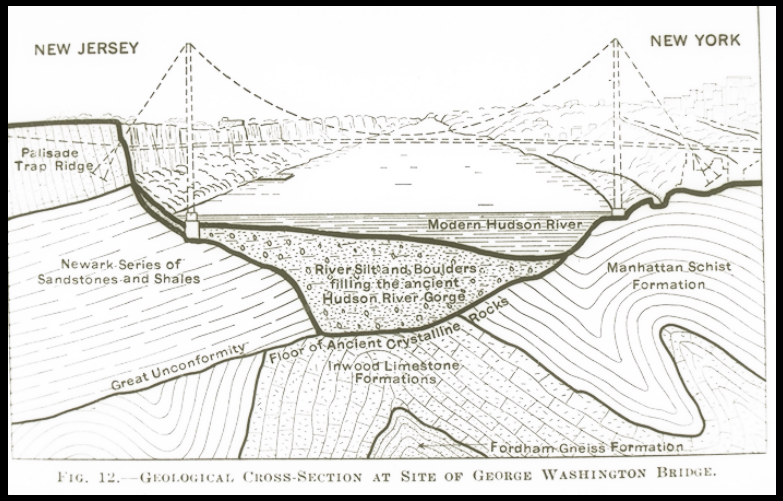
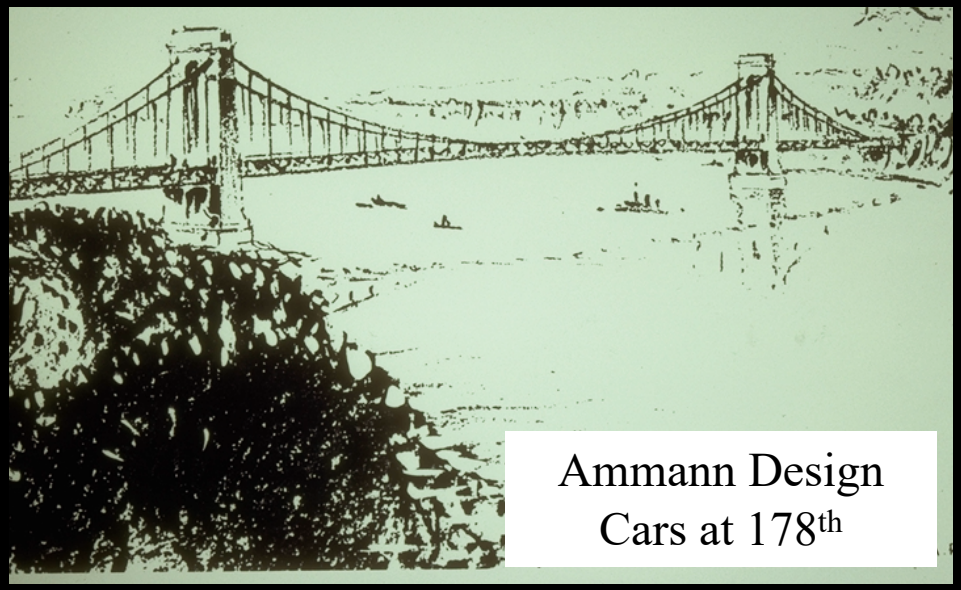


FIG. 12.—GEOLOGICAL CROSS-SECTION AT SITE OF GEORGE WASHINGTON BRIDGE.



Ammann Design
Cars at 178th

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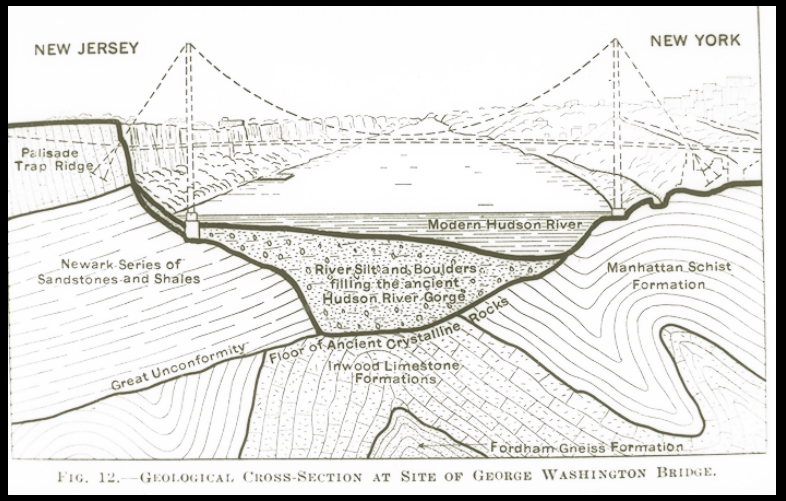

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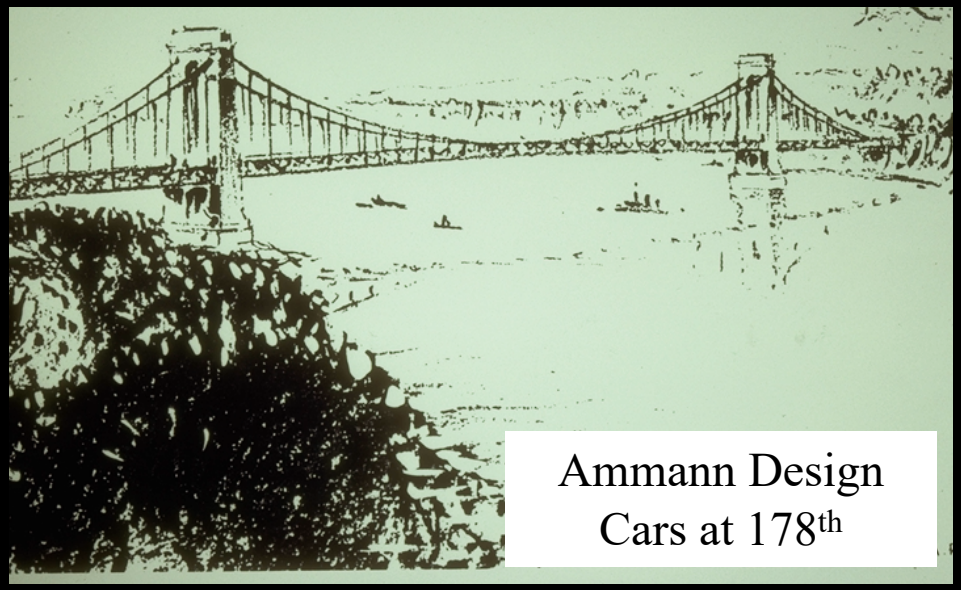

Ammann Design
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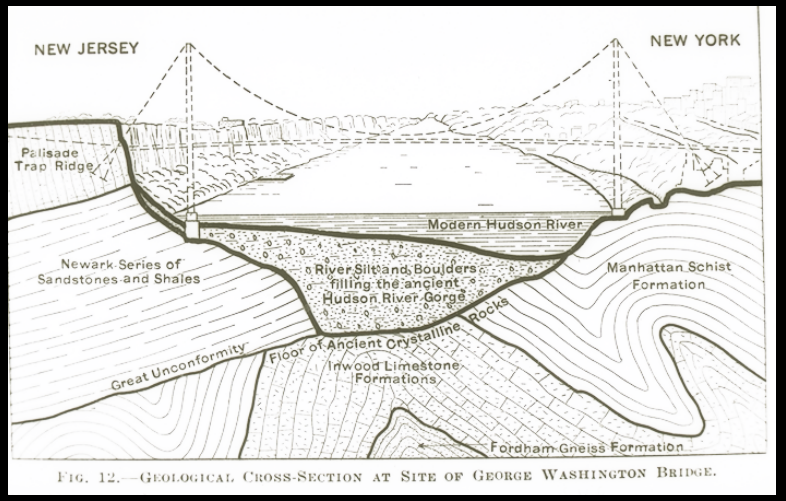

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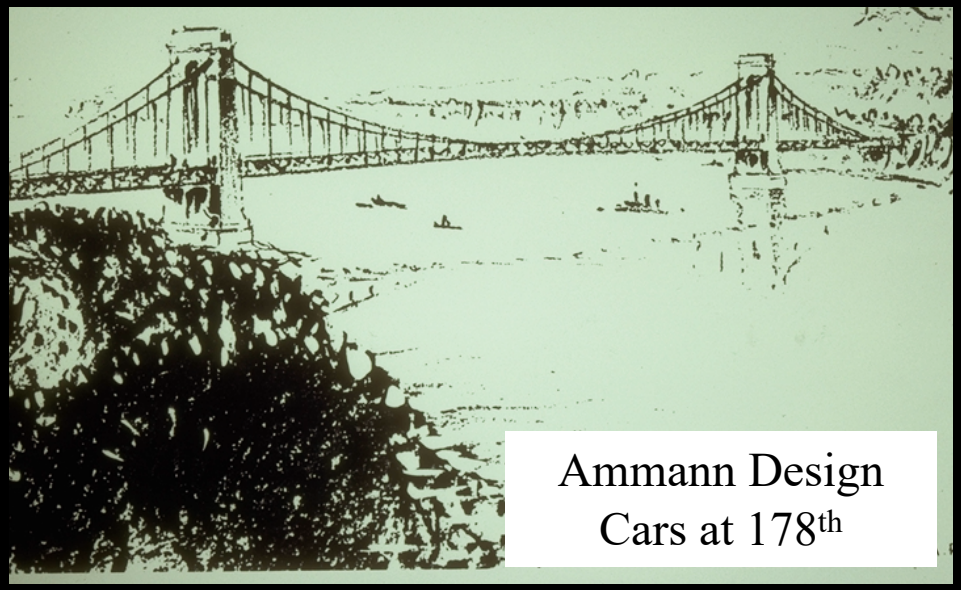

Ammann Design
Cars at 178th

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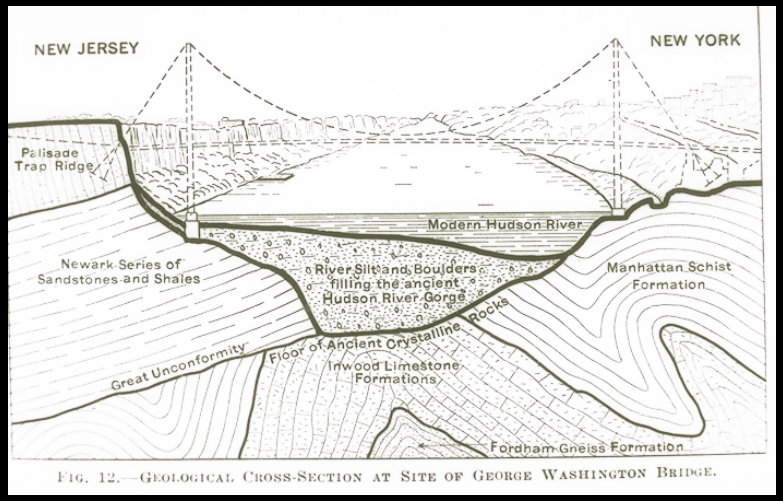

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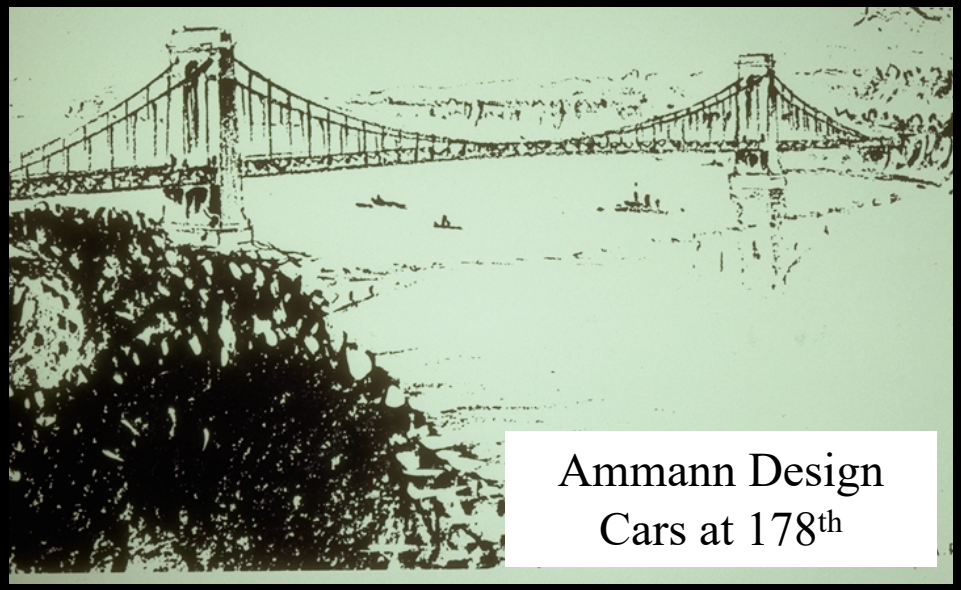

Ammann Design
Cars at 178th

George Washington Bridge - 1931

The George Washington Bridge
SOCIAL

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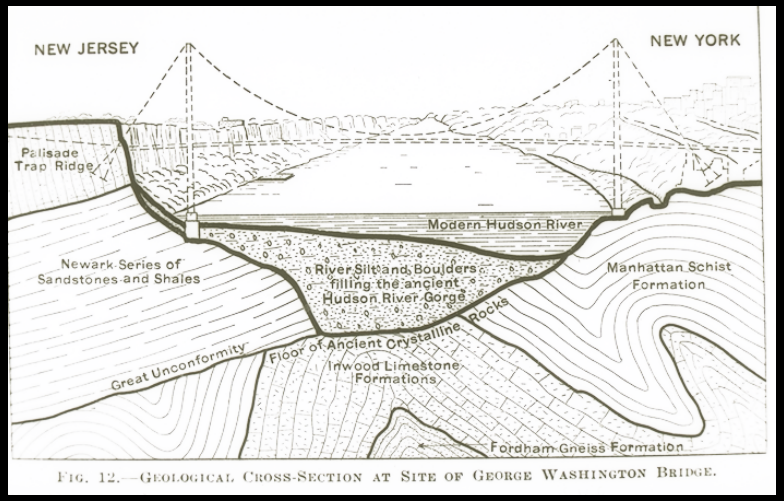

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George Washington Bridge - 1931

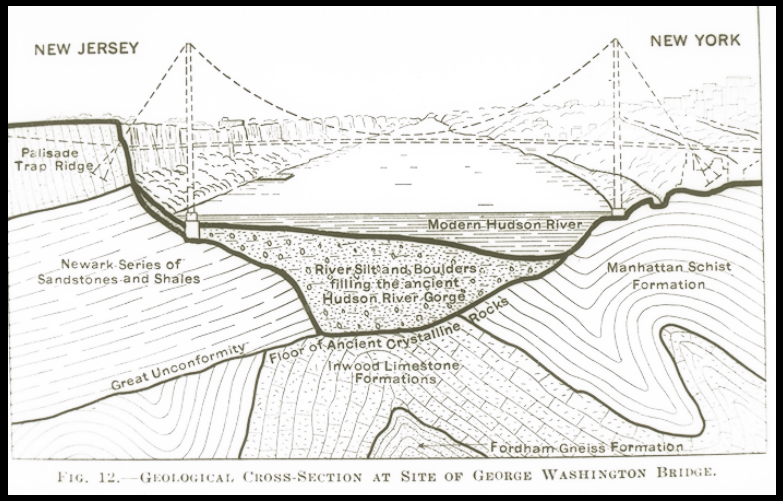


FIG. 12.—GEOLOGICAL CROSS-SECTION AT SITE OF GEORGE WASHINGTON BRIDGE.

George Washington Bridge - 1931

Bayonne Bridge - 1931

George Washington Bridge - 1931

Hell Gate Bridge - 1917

Bayonne Bridge - 1931

George Washington Bridge - 1931

Hell Gate Bridge - 1917

Bayonne Bridge - 1931

"… the controlling criteria in selecting the system … (are) structural simplicity, maximum economy … , and aesthetic conception"

Othmar Ammann - 1933

George Washington Bridge - 1931

Bayonne Bridge - 1931

Life Magazine – Margaret Bourke-White

George Washington Bridge - 1931

Bayonne Bridge - 1931

Life Magazine – Margaret Bourke-White

Life Magazine – Margaret Bourke-White


LIFE

75th Anniversary Stamp

75th Anniversary Stamp

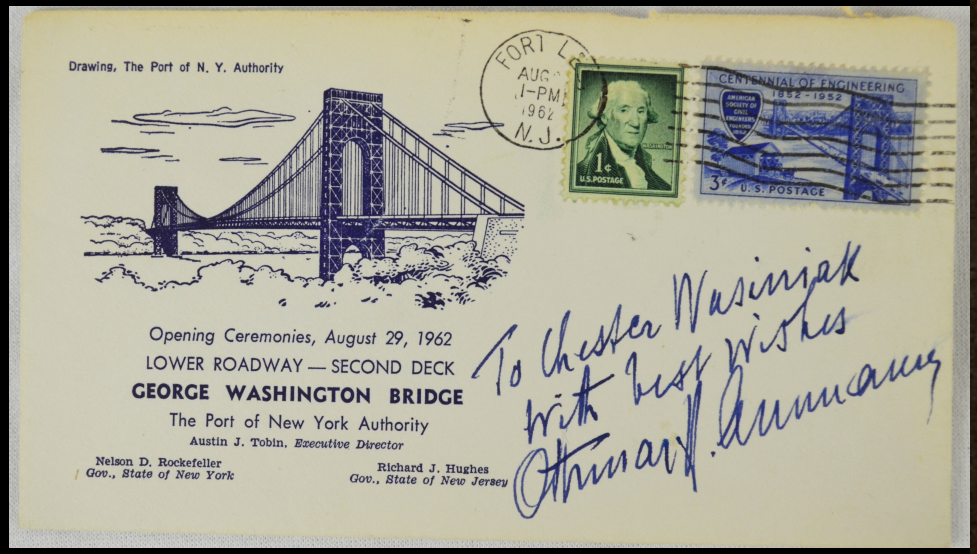
Port Authority Airports

Port Authority's Mission

Port Authority Airports

To identify and meet the critical transportation infrastructure needs of the bi-state region's businesses, residents and visitors: providing the highest quality, most efficient transportation and port commerce facilities and services that move people and goods within the region, provide access to the rest of the nation and to the world, and strengthen the economic competitiveness of the New York-New Jersey metropolitan region.

Port Authority Airports


Drawing, The Port of N. Y. Authority
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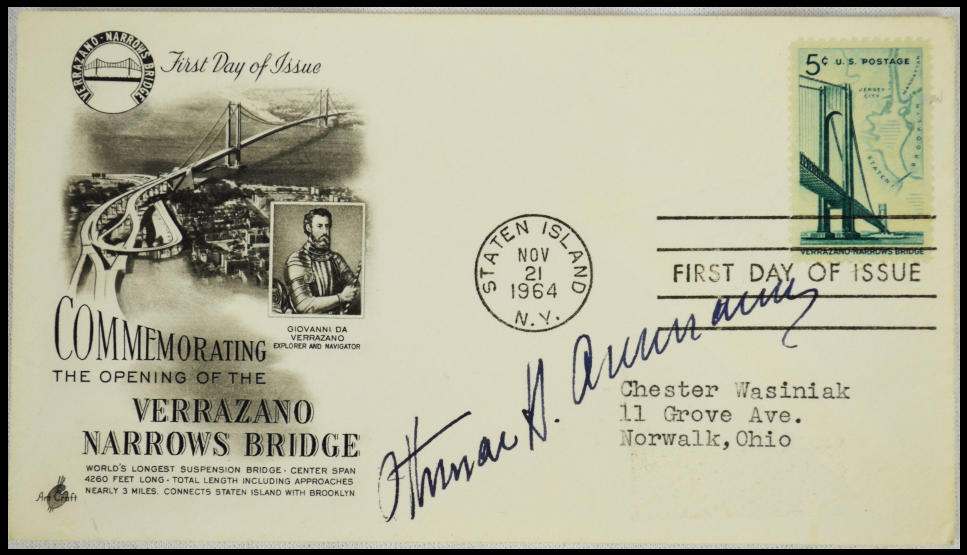
1962
N.J.
1¢ U.S. POSTAGE
CENTENNIAL OF ENGINEERING
1852 - 1952
3¢ U.S. POSTAGE
Opening Ceremonies, August 29, 1962
LOWER ROADWAY — SECOND DECK
GEORGE WASHINGTON BRIDGE
The Port of New York Authority
Austin J. Tobin, Executive Director
Nelson D. Rockefeller
Gov., State of New York
Richard J. Hughes
Gov., State of New Jersey
To Chester Wasiniak
with best wishes
Othmar H. Ammann


CENTENNIAL OF ENGINEERING
1852 - 1952
AMERICAN SOCIETY OF CIVIL ENGINEERS
FOUNDED 1852
3¢ U. S. POSTAGE


First Day of Issue
COMMEMORATING
GIOVANNI DA VERRAZANO
EXPLORER AND NAVIGATOR
THE OPENING OF THE
VERRAZANO NARROWS BRIDGE
WORLD'S LONGEST SUSPENSION BRIDGE · CENTER SPAN 4260 FEET LONG · TOTAL LENGTH INCLUDING APPROACHES NEARLY 3 MILES. CONNECTS STATEN ISLAND WITH BROOKLYN
STATEN ISLAND
NOV
21
1964
N.Y.
5¢ U. S. POSTAGE
VERRAZANO-NARROWS BRIDGE
FIRST DAY OF ISSUE
Othmar H. Ammann
Chester Wasiniak
11 Grove Ave.
Norwalk, Ohio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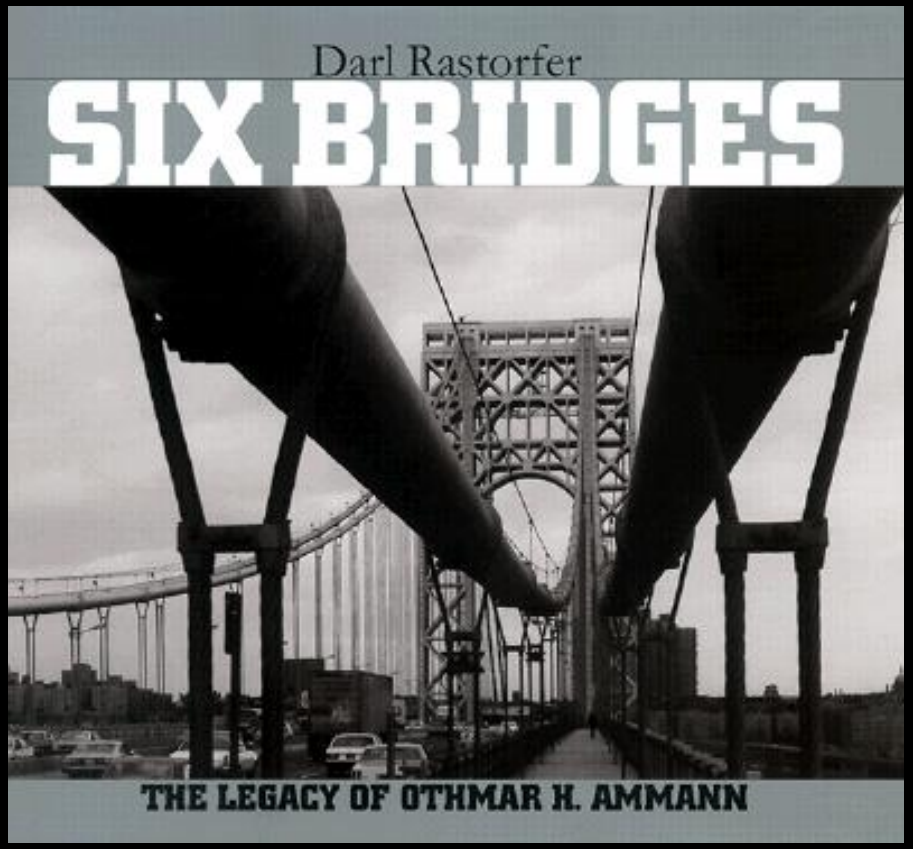
1879-1965
HELVETIA
20
HANS THONI
COURVOISIER

National Medal of Science - 1964

National Medal of Science - 1964



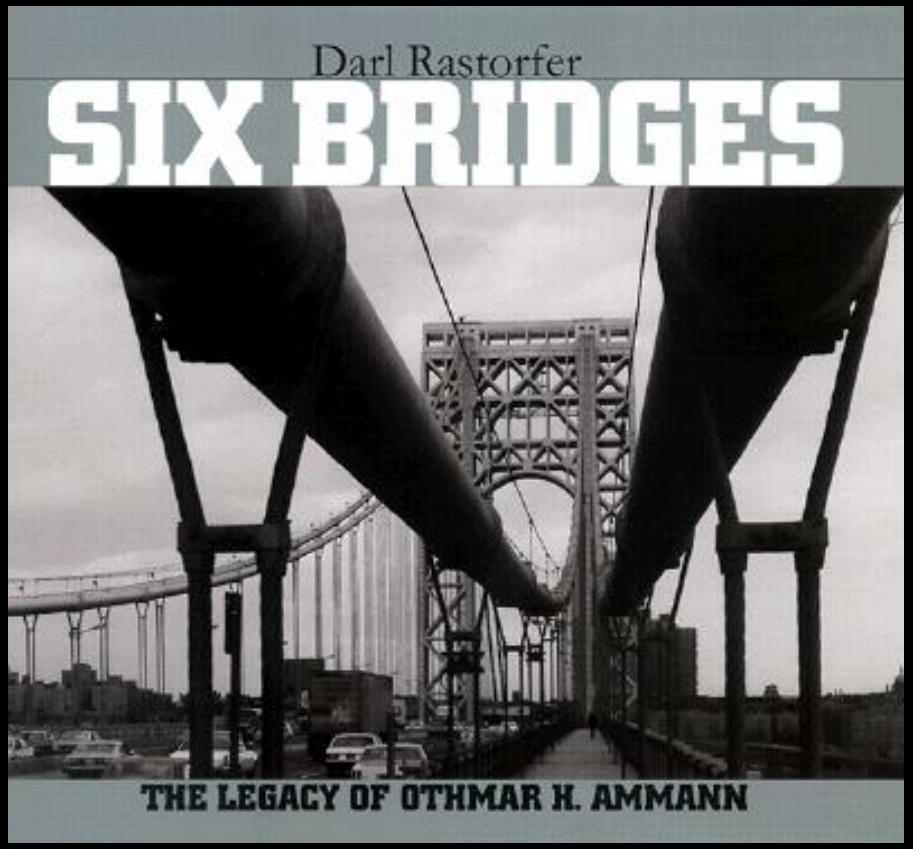
George Washington	– 1931
Bayonne	– 1931
Robert F. Kennedy	– 1936
Bronx-Whitestone	– 1939
Throgs Neck	– 1961
Verrazano Narrows	– 1964

Key Ideas

Scientific: Lane Loading Analysis

Social: First Bi-State Agency

Symbolic: Iconic Structural Art



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