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**AMERICAN SOCIETY OF CIVIL ENGINEERS**

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**TRANSACTIONS**

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**Paper No. 1150**

**THE NEW YORK TUNNEL EXTENSION OF  
THE PENNSYLVANIA RAILROAD.**

**BY CHARLES W. RAYMOND, M. AM. SOC. C. E. <sup>[A]</sup>**

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Some time before the appointment of the Board of Engineers which supervised the designing and construction of the New York Tunnel Extension of the Pennsylvania Railroad, the late A. J. Cassatt, then President of the Company, said to the writer that for many years he had been unable to reconcile himself to the idea that a railroad system like the Pennsylvania should be prevented from entering the most important and populous city in the country by a river less than one mile wide. The result of this thought was the tunnel extension project now nearly completed; but it is only in recent years that new conditions have rendered such a solution of the problem practicable as well as desirable.

Previously a tunnel designed for steam railroad traffic, to enter New York City near Christopher Street, was partly constructed, but the work was abandoned for financial reasons. Then plans for a great suspension bridge, to enable all the railroads reaching the west shore of the North River to enter the city at the foot of 23d Street, were carefully worked out by the North River Bridge Company. The Pennsylvania Railroad Company gave this project its support by agreeing to pay its *pro rata* share for the use of the bridge; but the other railroads declined to participate, and the execution of this plan was not undertaken.

New operating conditions, resulting from the application of electric traction to the movement of heavy railroad trains, which had been used initially in tunnels by the Baltimore and Ohio Railroad and was subsequently studied and adopted by railroads in Europe, made it possible to avoid the difficulty of ventilation connected with steam traction in tunnels, and permitted the use of grades practically prohibitive with the steam locomotive. The practicability of the tunnel extension project finally adopted was thus assured.

The acquisition of the control of the Long Island Railroad by the Pennsylvania Railroad Company,

[1]

[2]

which occurred in 1900, introduced new and important elements into the transportation problem, from a freight as well as a passenger standpoint. Previously, the plans considered had for their only object the establishment of a convenient terminus in New York, to avoid the delays and difficulties involved in the necessity of transporting passengers and freight across the North River. When the Long Island Railroad became practically a part of the Pennsylvania System, it was possible and desirable to extend the project so as to provide, not only for a great prospective local traffic from all parts of Long Island, but also for through passenger and freight traffic to the New England States, and to and from all points on the Pennsylvania System, thus avoiding the long ferriage from Jersey City around the harbor to the Harlem River.

This paper has for its subject the New York Tunnel Extension project, and is intended merely as an introduction to the detailed accounts of the construction of the various divisions of the line to be given in succeeding papers prepared by the engineers who actively carried out the work. The project, however, forms the most important part of the comprehensive scheme adopted by the Pennsylvania Railroad Company for conducting its traffic into and through New York City, and a brief description of this general plan is therefore necessary in order that the relations of the tunnel line to the other parts of the transportation project may be clearly understood. [3]

#### GENERAL PLAN FOR TRAFFIC FACILITIES AT NEW YORK.

The component elements of the general plan outlined by the late A. J. Cassatt, President, in his open letter to the Board of Rapid Transit Railroad Commissioners of the City of New York, dated January 18th, 1906, are indicated on Fig. 1, and may be briefly summarized as follows:

1.—The Pennsylvania Tunnel and Terminal Railroad, generally referred to as the New York Tunnel Extension of the Pennsylvania Railroad. This line begins near Newark, N. J., crosses the Hackensack Meadows, and passes through Bergen Hill and under the North River, the Borough of Manhattan, and the East River to the large terminal yard, known as Sunnyside Yard, in Long Island City, Borough of Queens, New York. The line will be more fully described elsewhere.

2.—The electrification of the Long Island Railroad within the city limits.

3.—The Pennsylvania freight terminal yard and piers at Greenville, N. J., connecting by ferry with the Bay Ridge terminal of the Long Island Railroad.

4.—The Bay Ridge Improvement of the Long Island Railroad from East New York to Bay Ridge.

5.—Yards for increasing the freight facilities in the Boroughs of Brooklyn and Queens.

6.—The Atlantic Avenue Improvement in Brooklyn, involving the removal of the steam railroad surface tracks and the extensive improvement of the passenger and freight station at Flatbush Avenue.

7.—The New York Connecting Railroad, extending through a part of the Borough of Queens and crossing the East River by a bridge at Ward's and Randall's Islands to Port Morris, N. Y.

8.—The Glendale Cut-Off of the Long Island Railroad.

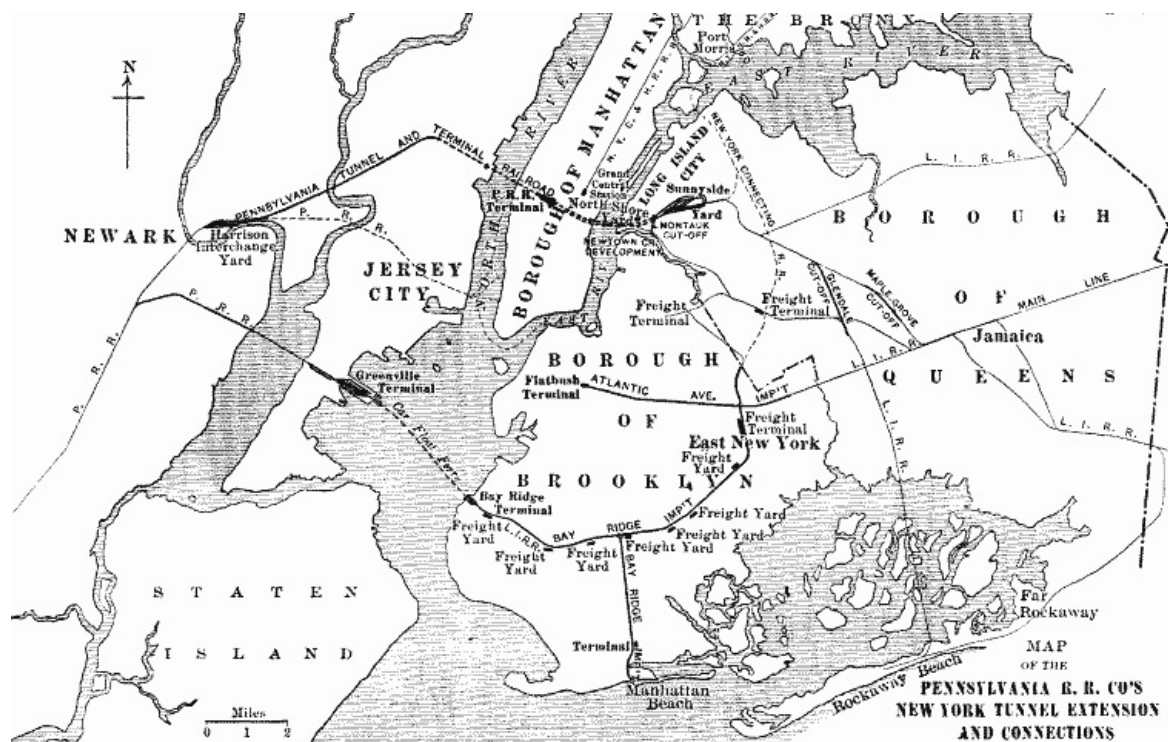
9.—New piers and docks in Newtown Creek at its confluence with the East River.

10.—Electrification of the United Railroads of New Jersey Division from Newark to Jersey City.

The parts sustained by these elements in the work of transportation and distribution are briefly as follows:

The New York Tunnel Extension is essentially a passenger line, although the Company has not only the legal powers but also the facilities for making it a through route for freight if desired. It will transport passengers to and from the centrally located station at 33d Street and Seventh Avenue in New York City, joining the Long Island System at Sunnyside Yard, and, by means of the New York Connecting Railroad, it will form a link in the through traffic line, connecting the whole Pennsylvania System with the New England States. This line has been designed for the safe and expeditious handling of a large volume of traffic. The requirements include handling the heaviest through express trains south and west from the main line as well as the frequent and lighter local-service trains. For through service the locomotive principle of operation has been adhered to, that is, electric locomotives will take up the work of the steam locomotives at the interchange yard at Harrison, N. J., and, for excursion and suburban service to nearby towns, provision will be made for electric locomotives, or by operation of special self-propelled motor cars in trains, the project being planned to give the greatest flexibility in method of operation to meet the growing demand in the best way. [4]

The New York Connecting Railroad has important functions both for freight and passenger service. When constructed it will be about 12 miles long, and will form a part of the line to the New England States for through passenger and freight service, and also carry local freight to and from Sunnyside Yard and Brooklyn, and all points on Long Island. By means of this line it will be possible to make the Brooklyn station at Flatbush Avenue a station on the through System for New England as well as the Western States.



**Fig. 1. (Full page image)**  
**MAP OF THE PENNSYLVANIA R. R. CO'S NEW YORK TUNNEL EXTENSION AND CONNECTIONS.**

The initial equipment of the Western Division of the Long Island Railroad for electric traction has been made in advance of the opening of the tunnel line in order to take care of the requirements of the Atlantic Avenue improvement. This improvement involved the elimination of grade crossings within the City of Brooklyn and the conversion of the railroad line which was previously on the surface of the streets to part subway and part elevated line from the Flatbush Avenue Terminal to East New York Station, a distance of 5-1/4 miles. One of the requirements of this improvement was that the motive power should be changed to some form of power not involving combustion. This led to the adoption of electricity, and, in order to meet operating necessities, involved the electrification of connecting lines beyond the improvement proper, so that local service could be handled to the end of the runs without changing the motive power. The extent of the electrification thus required was found to be about 100 single-track miles. This extensive electrification work was undertaken and completed in the summer of 1905, upon the completion of the Atlantic Avenue improvement proper, and since that time has been in successful operation. On the near approach of the construction of the New York Terminal improvement, plans for additional electrification on the Long Island Railroad were made, and the work is now in progress on the extensive additions required to couple up the tunnel extension with the various lines centering at the Long Island City terminus.

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The Bay Ridge Improvement of the Long Island Railroad comprises the readjustment of the right of way and the establishment of new grades in order to do away with grade crossings from the freight terminal at Bay Ridge to a junction with the New York Connecting Railroad at East New York, a distance of 10.4 miles. It also provides for the re-location of the line and the elimination of grade crossings on the branch running to Manhattan Beach, a distance of 3.7 miles. The work is being executed without interrupting traffic, and in all about 75 grade crossings will be abolished. This improvement became necessary in order to provide for the rapid extension of population into the suburban districts and for the present and future requirements of the section, to establish municipal conveniences and facilities, and to open additional streets across the right of way. To accomplish these ends, the line has been built in cuts and on embankments, there being about 6.4 miles of the former, 3.3 miles of the latter, and a tunnel, 3,500 ft. long, where the line crosses the Atlantic Avenue improvement.

The Atlantic Avenue improvement, as mentioned above, involved the removal of the railroad tracks from the street surface for a distance of about 5-1/4 miles. This was done by constructing a series of elevated and subway structures, there being about 2.1 miles of the former, 2.4 miles of the latter, and 0.8 mile of approaches, eliminating more than 90 grade crossings. In the light of recent developments, it may be of interest to note that one of the reasons for establishing a combination elevated and subway line was that, at the time the improvement was projected, no underground railroad in the country, of similar length and carrying a heavy volume of local traffic, was operated by electricity, and public sentiment was against the operation of the entire length of the line underground by steam power. This improvement also provided for depressing the entire Flatbush Avenue station and a freight yard. As the work progressed, the original plans for the station were greatly enlarged, the remodeled station covering about 61 city lots.

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The main point of passenger distribution is the New York station. Other important stations will be Flatbush Avenue, Brooklyn; Jamaica, Long Island, where the changes to and from electric motive power will be made; and Newark, N. J. Many other places, including the seaside resorts on Long Island and in New Jersey, will feel the benefits of the direct tunnel railroad into and through New

York City. The Glendale Cut-Off will materially shorten the route and running time from New York through the tunnels to Rockaway Beach.

The plans contemplate that passengers to and from the lower part of Manhattan will be carried by the steam line between Newark and Jersey City and cross the North River by ferry or the Cortlandt Street tunnels of the Hudson Company. Eventually, the old main line will be electrified and supersede the steam service between Newark and Jersey City.

The Greenville Yard is the most important point for the receipt, transmission, and distribution of freight. From this point freight can be transported, without breaking bulk, by a comparatively short car-ferry to the Long Island Railroad terminus at Bay Ridge, and thus a very large part of the Pennsylvania Railroad Company's floatage in New York Harbor and the East River will be abolished, the floatage distance being reduced in the case of the New England freight from about 12 to 3 miles. This traffic will be routed from Bay Ridge *via* the Long Island Railroad to a connection with and thence over the New York Connecting Railroad to the New York, New Haven and Hartford Railroad at Port Morris, N. Y.

As the facilities for the handling of freight in the Boroughs of Brooklyn and Queens had become insufficient for taking care of the prospective traffic, eleven new local delivery yards, having a combined area of about 2,153 city lots, have been established, and three existing yards are to be improved and enlarged so as to give a combined area of about 687 city lots. Of these new yards, the Bay Ridge freight terminal, containing about 790 city lots, is the largest; its functions have been described above. There is a freight terminal at East New York 200 ft. wide and a mile long, containing about 566 city lots, which will be the distributing point of freight for the entire East New York section. This yard is depressed, and will be crossed by six viaducts carrying city streets. The North Shore freight yard, containing 109 city lots, is connected with the Montauk Division by an overhead construction, known as the Montauk Freight Cut-Off, whereby all freight traffic to Jamaica may be kept out of the way of the Jamaica passenger traffic from the tunnels.

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It may be of interest to indicate briefly how much has already been accomplished in the execution of this general plan, and what still remains to be done for its completion.

The larger part of the electrification of the Long Island Railroad and the elimination of grade crossings within the built-up city limits, the Atlantic Avenue improvement, and the yard and piers at Greenville, have been completed. The Sunnyside Yard and the Glendale Cut-Off will be completed during the next twelve months. On the Tunnel and Terminal Railroad the embankment and bridge work across the Hackensack Meadows and all the tunnels and excavation from the west side of Bergen Hill to Long Island City, except a short section near the eastern end of the line, have been completed. The New York station and other buildings and facilities connected therewith are well advanced. The laying of the track, the electrification of the line, and the installation of the signaling and lighting systems are under way. It is anticipated that the line will be ready for operation in the spring of 1910.

Report has been made to the Public Service Commission that a large part of the right of way for the New York Connecting Railroad has been obtained, and more than \$3,000,000 has been spent by this railroad. The piers and docks at Newtown Creek and the electrification of the line from Newark to Jersey City are not yet actively under way.

#### ESTIMATED COST OF THE IMPROVEMENTS.

As appears from the foregoing statement, only parts of the improvements contemplated in the general scheme have been completed, others are in progress, and others have not yet been commenced. It is therefore impossible at the present time to make a close estimate of the total expenditure involved in the execution of the entire scheme. The following estimate of the cost of the Pennsylvania Railroad Company's improvements in the New York District when fully completed is based on the best information now available:

[9]

New York Tunnel Extension and Station, including Interchange Yards at Harrison, N. J., and Sunnyside, L. I., P. T. & T. R. R. Co.	\$100,000,000
Long Island Railroad electrification, Bay Ridge and Atlantic Avenue improvements, Glendale Cut-Off, freight yards, and new equipment	35,000,000
New York Connecting Railroad, to be built jointly by the Pennsylvania R. R. Co. and the New York, New Haven and Hartford R. R. Co., about	14,000,000
Pennsylvania Railroad improvements in the State of New Jersey, electrification of line from Jersey City to Park Place, Newark, Greenville freight line and terminal on New York Bay	10,000,000
Total	\$159,000,000

#### CORPORATE ORGANIZATION AND FRANCHISE CONDITIONS.

As the tunnel extension lies partly in the State of New Jersey and partly in the State of New York, it was necessary to charter two companies, each covering the territory within the State to which it belonged. The New Jersey corporation was entitled the Pennsylvania, New Jersey and New

York Railroad Company, and the New York corporation, the Pennsylvania, New York and Long Island Railroad Company. These organizations were completed early in 1902. Subsequently, after the tunnels had been joined under the North River, the companies were consolidated, on June 26th, 1907, and thereby formed the present company under the name of the Pennsylvania Tunnel and Terminal Railroad Company, a corporation of both States.

Mr. Cassatt, President of the Pennsylvania, New York and Long Island Railroad Company, made application in its behalf for a franchise to extend the lines of the Pennsylvania Railroad by tunnels under the North River to a passenger station to be erected in New York City and thence under the East River to a connection with the Long Island Railroad, on May 5th, 1902. [10]

The franchise for that part of the tunnel line which is within the State of New York, that is, from the boundary line between New York and New Jersey, in the Hudson River, to the eastern terminus at Sunnyside Yard, Long Island, is contained in the certificate issued by the Board of Rapid Transit Railroad Commissioners of the City of New York on October 9th, 1902.

The essential features of the franchise have been summarized substantially as follows in the report of the Committee of the Board of Rapid Transit Railroad Commissioners of the City of New York, dated June 14th, 1902:

*First.*—A grant by the city in perpetuity of rights, subject, however, to a periodic readjustment of payments at intervals of twenty-five years, as follows:

(a) To construct and operate a railroad of two tracks from the boundary between New York and New Jersey under the Hudson River opposite the westerly foot of Thirty-first Street, Borough of Manhattan, thence running under the Hudson River and Thirty-first Street to the East River and under the East River to a terminus in Queens Borough. The Company is permitted on notice within ten years to give up the right to these two tracks.

(b) A like right for a railroad of two tracks beginning near the same point under the Hudson River, thence running under Thirty-second Street to the East River, and under that river to the terminus in Queens Borough, with a right for two additional tracks in Thirty-second Street, west of Ninth Avenue, and one additional track between Seventh and Fifth Avenues in Manhattan.

(c) A like right for a railroad of two tracks beginning at the station terminal site at Thirty-third Street and Seventh Avenue and thence running under Thirty-third Street and the East River to the terminal in Queens Borough, with a right for one additional track on Thirty-third Street, between Seventh and Fifth Avenues.

(d) A right to maintain a terminal station occupying the four blocks bounded by Thirty-first Street, Seventh Avenue, Thirty-third Street and Ninth Avenue, the lots on the east side of Seventh Avenue between Thirty-first and Thirty-third Streets, and the underground portions of Thirty-first and Thirty-third Streets, between Seventh and Eighth Avenues and between Eighth and Ninth Avenues, the Company having itself acquired the land included in such four blocks and lots on the east side of Seventh Avenue. [11]

(e) To occupy for such terminal facilities all of Thirty-second Street lying between the westerly side of Seventh Avenue and the easterly side of Eighth Avenue, and between the westerly side of Eighth Avenue and the easterly side of Ninth Avenue. As soon as the statutory right of the city authorities to make the conveyance shall be put beyond doubt the Railroad Company is obliged to buy such two portions of Thirty-second Street, which will then become completely dedicated to the purposes of their station. (These portions of Thirty-second Street were subsequently purchased by the Railroad Company.)

(f) To have along such routes the necessary facilities for the operation of passenger and freight trains, including telegraph wires and the various wires and cables for the distribution of power, heat, and light.

*Second.*—The requirement of the consent of the Mayor, the Board of Aldermen, the Board of Estimate and Apportionment, and the other authorities of the city having control of the streets.

*Third.*—The obligation of the Pennsylvania Company to begin construction within three months after obtaining the necessary consents and complete the railroad within five years after construction shall begin, except the route under Thirty-first Street, for the completion of which the company is allowed ten years after the completion of the remainder of the railroad.

*Fourth.*—Payments by the Pennsylvania Company for the first twenty-five years, as follows: A rental of \$200 per annum for the right to occupy land under the Hudson and East Rivers outside of pier lines. A rental for ground within pier lines and for underground portions of streets in Manhattan Borough, at fifty cents per linear foot of single track per annum, for the first ten years, and during the next fifteen years one dollar per annum per linear foot. A rental for ground within pier lines and for underground portions of streets in Queens Borough at one-half the rates payable for Manhattan Borough. A rental for underground portions of Thirty-first and Thirty-third Streets, between Seventh and Eighth Avenues, and between Eighth and Ninth Avenues (such portions extending almost up to the surface, except under the south sidewalk of Thirty-first

Street and north sidewalk of Thirty-third Street) at \$14,000 per annum for the first ten years, and at \$28,000 per annum for the next fifteen years.

For the portions of Thirty-second Street, between Seventh and Eighth Avenues, and between Eighth and Ninth Avenues, when the statutory power of the city to make a sale shall be put beyond doubt, the city is to sell and the Railroad Company is required to buy such portions for the sum of \$788,600. The rentals for river and track rights begin at the date of operation. For the underground spaces under Thirty-first and Thirty-third Streets, used for station extension, the rentals begin at the commencement of construction, or when the company entered thereon.

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Such annual payments may be summarized as follows:

	First 10 years.	Next 15 years.
For river rights	\$200.00	\$200.00
For tunnel rights in Manhattan Borough, being 44,341 ft. (partly estimated) of single track	22,170.00	44,341.00
For tunnel rights in Queens Borough, being 8,100 ft. (partly estimated) of single track	2,025.00	4,050.00
For street rights on Thirty-first and Thirty-third Streets, north and south of terminal	14,000.00	28,000.00
In all, per annum	\$38,395.00	\$76,591.00

If the route under Thirty-first Street be availed of, these amounts will be increased by \$16,652.50 for the first ten years, and by \$33,305 for the next fifteen years.

The amounts to be paid are to be readjusted at the end of twenty-five years; and thereafter at intervals of twenty-five years. If the city and the Railroad Company shall not agree upon the readjusted rates, they are to be determined by the Supreme Court of this State.

*Fifth.*—The railroad to be entirely in tunnel except where it approaches the surface at its eastern terminal near Thomson Avenue, in Queens Borough. The uppermost part of the tunnel is to be at least nineteen feet below the surface of the street; but this limitation does not apply to the portions of Thirty-first and Thirty-third Streets opposite the terminal station between Seventh and Ninth Avenues, where the Company may occupy the underground portions of the street under the roadway to within thirty inches of the surface, and under the sidewalks on Thirty-first and Thirty-third Streets opposite to the station to within five feet of the surface, the company to properly care for sewers, water, gas and other pipes and underground structures lawfully in the street.

*Sixth.*—The company to make good all damage done to property of the city by its construction work or operations, and to abutting owners all damage done through any fault or negligence of the company, or of any contractor or sub-contractor engaged upon its work of construction or operation. The Tunnel Company to keep Thirty-first and Thirty-third Streets opposite the station well paved with smooth pavement and in thoroughly good condition.

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*Seventh.*—Tunnel excavations to be done without disturbing the surface of the street, except in the portions of Thirty-first and Thirty-third Streets, and Seventh, Eighth and Ninth Avenues in front of the terminal station, and except in Queens Borough, with the power to the Rapid Transit Board, wherever conditions elsewhere make surface excavation necessary for efficient construction, to grant the right for such excavation, subject to conditions to be then prescribed by the Board. The tracks are to be constructed of the most approved plan so as to avoid noise or tremor. All plans for, and the method of doing, the work are made subject to the approval of the Rapid Transit Board.

*Eighth.*—The motive power to be electricity, or such other power not involving combustion as may be approved by the Board.

*Ninth.*—The company to have no power to carry on merely local traffic, except with the approval of the Board and for additional consideration to be paid the city. Traffic is defined as local which begins and ends in the city within five miles of the terminal station on Seventh and Ninth Avenues.

*Tenth.*—The railroad to be diligently and skillfully operated, with due regard to the convenience of the traveling public.

*Eleventh.*—The city to have a lien upon the franchise and real property of the company to secure the payment of rental.

*Twelfth.*—The rights of the city to be enforceable by action, for specific performance, or mandamus, or otherwise.

*Thirteenth.*—The company not to oppose the construction of any rapid transit railroad along or across the same routes which do not actually interfere with the authorized structures of the company.

*Fourteenth.*—The city to have an ample right of inspection of the railroad, and to enter upon it for examination, supervision, or care of city property, or for other purposes.

*Fifteenth.*—The company to be bound to maintain and strengthen all parts of its railways under streets or avenues so that the same shall support safely any structures superimposed or which may hereafter be superimposed thereon by the city or under public authority.

*Sixteenth.*—The company to have the right to convey or mortgage the franchise, but every grantee, whether directly or under a mortgage, to assume the obligations already assumed by the Railroad Company and the Railroad Company not to be relieved of such obligations by the grant.

This franchise was passed by the Board of Aldermen on December 16th and approved by the Mayor on December 23d, 1902.

Subsequently, an agreement, dated June 21st, 1907, was entered into by the City of New York, the Tunnel Company, and the Long Island Railroad Company covering the construction of the Sunnyside Yard, which forms the eastern terminus of the line. [14]

In pursuance of this agreement, the map or plan of the City of New York was changed by discontinuing or closing portions of fifty streets or avenues, and by changing the grades of sixteen streets or avenues, in the Borough of Queens, and the portions of streets and avenues thus discontinued and closed, most of which were not opened for public use, were sold to the Railroad Companies. The agreement, however, reserved to the City permanent and perpetual underground rights and easements to maintain in a reasonable manner, not inconsistent with the construction and operation of the railroad facilities of the Companies, its existing sewers, drains, and other sub-surface structures in, under, and through the lands within the lines of the discontinued portions of each of such streets and avenues, including the right to repair, rebuild, and enlarge the same, and to construct in a reasonable manner, not inconsistent with the construction and operation of the railroad facilities of the Companies, such additional sewers or drains in, under, or through the lands as may be hereafter required by the City, together with the right to enter upon the premises from time to time as may be necessary for the purpose of inspecting, repairing, constructing, or rebuilding the sub-surface structures.

The agreement required the Companies to construct at their expense, four viaducts or bridges over their tracks and terminal development, three with roadways 42 ft. wide, one with a roadway 60 ft. wide, and each to have two sidewalks 10 ft. wide, the work to include the paving of the roadways and sidewalks.

The Companies are further required to pay one-half the cost of the construction of the foundations, abutments, piers, superstructures, and approach of an additional viaduct or bridge over the Sunnyside Yard, to have a roadway not more than 60 ft. wide and two sidewalks each 10 ft. wide, and to grant the City of New York a perpetual easement for the continuance of the same in the location upon which it shall be constructed.

The agreement further provides that the Companies shall not injure the sewers or other substructures now existing or hereafter constructed under the streets and avenues, and, in case of injury, that they shall repair them or pay the cost thereof; that the viaducts shall be completed within the shortest time consistent with their safe and proper construction, and that during their construction temporary streets shall be provided for the accommodation of traffic. [15]

The Companies are required to bear all the expense of changes of grade in the streets and avenues, except those made necessary by the construction of the viaduct or bridge to be paid for in part by the City; to indemnify the City against all liability for any and all damages which may accrue on account of any street which may be closed or the grades of which may be changed in pursuance of the agreement; to assume all liabilities by reason of the construction or operation of the railroads, or the construction of the viaducts, and to save the city harmless from any liability whatever, to either persons or property, by reason of the construction or operation of the railroads or the construction of the viaducts.

The Companies are also required to indemnify the City against and pay the cost of all alterations which may be required to the sewerage or drainage system or to any sub-surface structures and pipes laid in the streets or avenues on account of the construction and operation of the terminal, passenger yard, or freight yard of the Companies, or on account of the changes in grades or street system.

The Companies are authorized, if they deem it necessary to the construction or to the efficient operation of the terminal passenger yard or freight yard, to depress, at their expense, any pipes or other sub-surface structures now under the surface of any of the portions of the streets or avenues discontinued or closed, or to elevate and carry the same upon any of the viaducts or bridges, the plans of such depression or elevation to be approved by the Board of Estimate and Apportionment.

All works within, upon, or over the public streets and avenues are subject to the supervision and inspection of the proper municipal officer or officers, under such regulations as he or they may determine and be authorized by law to impose; and the plans for the construction of viaducts or bridges are to be approved by the Board of Estimate and Apportionment.

The Companies are required to cede to the City of New York perpetual easements for the right to continue and maintain the viaducts or bridges over the streets and avenues, sufficient for their control by the City for the purpose of police regulation and other control contemplated by the City ordinances for the case of streets or highways; reserving, however, the right to construct and maintain, at their own expense, such connections between the viaducts or bridges and their [16]

property as shall not interfere with the use of the viaducts or bridges for street purposes.

The Companies are also required to cede to the City, grade and curb, portions of five existing or proposed streets or avenues, and to pave portions of two other avenues.

Mr. A. J. Cassatt, President of the Pennsylvania Railroad Company, was President of the Companies constituting the New York Tunnel Extension until his death on December 28th, 1906, and Mr. James McCrea, President of the Pennsylvania Railroad Company, was elected his successor, and is now President of the Pennsylvania Tunnel and Terminal Railroad Company.

Mr. Samuel Rea, Second Vice-President of the Pennsylvania Railroad Company, has served as Vice-President since the incorporation of the enterprise.

Mr. A. J. County has been Assistant to the President since June 26th, 1907, and prior thereto and from the incorporation of the tunnel enterprise served as Secretary of the Pennsylvania, New Jersey and New York Railroad Company and as Assistant Secretary of the Pennsylvania, New York and Long Island Railroad Company, which, as heretofore stated, constitute the Pennsylvania Tunnel and Terminal Railroad Company.

#### ENGINEERING ORGANIZATION.

Mr. Rea, Vice-President, has general charge of all matters involved in the designing and execution of the project.

*The Board of Engineers.*—Before the beginning of the work, the Management appointed a Board of Engineers which was instructed to examine into the New York Tunnel Extension project; to pass upon the practicability of the undertaking; to determine upon the best plans for carrying it out; to make a careful estimate of its cost; and, if the work was undertaken, to exercise general supervision over its construction.

President Cassatt's letter appointing the Board contains the following further instructions:

"You are requested to procure all additional information that may be needed, sparing neither time nor any necessary expense in doing so, for I am sure it is not necessary for me to say that, in view of the magnitude and great cost of the proposed construction, and of the novel engineering questions involved, your studies should be thorough and exhaustive, and should be based upon absolute knowledge of the conditions."

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The Board was organized on January 11th, 1902, when it held its first session, and continued in the performance of its duties until April 30th, 1909, when it was dissolved, its work having been completed.

The Board held regular and special sessions to receive progress reports from the Chief Engineers in direct charge of construction, and to consider questions relating to the plans and details of the work submitted by its members or referred to it by the Management. It then reported its conclusions to the Vice-President for approval before the work was undertaken.

The Management earnestly impressed upon the Board throughout the whole period of its labors, that the Tunnel Extension and facilities were to be designed and constructed without regarding cost as a governing factor, the main considerations being safety, durability, and proper accommodation of the traffic. No expenditure tending to insure these conditions was to be avoided.

The Board, when organized, was composed as follows: Col. Charles W. Raymond, Corps of Engineers, U. S. Army, Chairman; Messrs. Gustav Lindenthal, Charles M. Jacobs, Alfred Noble, and William H. Brown.

Mr. George Gibbs was appointed a member of the Board on April 9th, 1902. Mr. Lindenthal resigned on December 15th, 1903, and Mr. Brown resigned on March 1st, 1906. Mr. Rea and all the members of the Board are members of the American Society of Civil Engineers, and Mr. Noble is a Past-President of the Society.

Mr. William R. Mead, of the firm of McKim, Mead, and White, Architects for the Terminal Station, was associated with the Board for the consideration of architectural subjects.

Mr. Robert H. Groff, Secretary of the Company, was also Secretary of the Board until his resignation on January 31st, 1907. Mr. William Couper was Acting-Secretary from April 15th, 1907, to April 30th, 1909.

S. Johannesson, Assoc. M. Am. Soc. C. E., was Engineer Assistant to the Chairman from December 1st, 1905, to April 30th, 1909.

*Division of the Work.*—For the purposes of actual construction, the line was divided into four parts: the Meadows Division, the North River Division, the Terminal Station, and the East River Division. A chief engineer appointed by the Management had charge of the construction of each Division. The chief engineers exercised full authority in the organization of the working forces, and in the general conduct and management of the work of construction on their respective Divisions, in accordance with the plans for such work approved by the Board of Engineers and the Management.

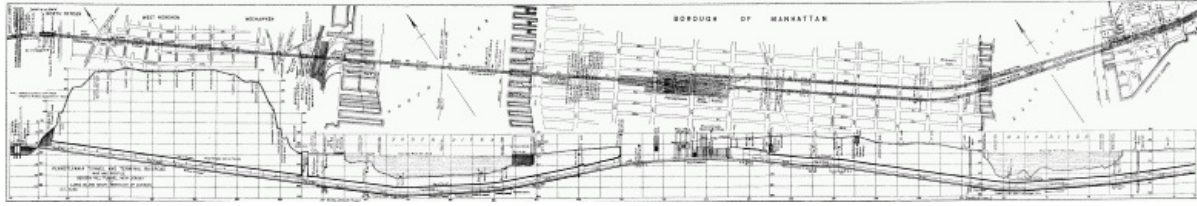
[18]

Architects were employed to design the Terminal Station building and superintend its erection; and structural engineers to design and erect steel structures and facilities, and carry on the work



under the direction of a Chief Engineer of the Company.

Committees, consisting principally of officers of the Pennsylvania Railroad Company, cooperating with the regular engineering organization, were appointed to consider the operating features of the project, so that the experience of the Pennsylvania Railroad Company's organization might be utilized in the work.



**Plate I.—Pennsylvania Tunnel and Terminal Railroad  
Map and Profile  
Bergen Hill Tunnel, New Jersey to Long Island Shaft, Borough of Queens**

DESCRIPTION OF THE LINE.

The following summary description of the various divisions of the line is intended to give a comprehensive idea of the general features of the project. Full details will be given in succeeding papers. The line and its respective divisions are shown on [Plate I](#).

*Meadows Division.*—Chief Engineer until March 1st, 1906, Mr. William H. Brown, Chief Engineer, Pennsylvania Railroad Company, when he retired from active service with the latter Company; since March 1st, 1906, Mr. Alexander C. Shand, Chief Engineer, Pennsylvania Railroad Company.

This Division consists of an "interchange yard" at Harrison, near Newark, N. J., adjoining the tracks of the present New York Division of the Pennsylvania Railroad, and a double-track railroad across the Hackensack Meadows to the west side of Bergen Hill, a distance of 6.04 miles. The construction is embankment and bridge work, including bridges across the Pennsylvania, Erie, and Lackawanna Railroads, and the Hackensack River.

*North River Division.*—Chief Engineer, Mr. Charles M. Jacobs.

This Division commences at the west side of Bergen Hill and passes through the hill in two single-track rock tunnels to a large permanent shaft at Weehawken, near the west shore of the North River, and thence eastward a distance of 224 ft. to the Weehawken shield-chamber. It then passes under the river through two cast-iron, concrete-lined, single-track tunnels, with outside diameters of 23 ft., to a point under 32d Street, near Eleventh Avenue, in New York City, and thence through two single-track tunnels of varying cross-section, partly constructed in cut-and-cover, to the east side of Tenth Avenue. It then passes into the Station Yard and terminates at the east building line of Ninth Avenue. The work included the Station Yard excavation and walls from Tenth Avenue to Ninth Avenue, and the retaining walls and temporary underpinning of Ninth Avenue. The aggregate length of the line in this Division is 2.76 miles.

[19]

*New York Station and Approaches.*—Mr. George Gibbs, Chief Engineer of Electric Traction and Station Construction.

The Station and its approaches extend from the east line of Tenth Avenue eastward to points in 32d Street and 33d Street, respectively, 292 ft. and 502 ft. east of the west line of Seventh Avenue. This Division included the construction of subways and bridges for the support of 31st and 33d Streets and Seventh, Eighth, and Ninth Avenues, the Station building between Seventh and Eighth Avenues, the foundations for the post office to be erected west of Eighth Avenue, the service power-house in 31st Street between Seventh and Eighth Avenues, the power-house in Long Island City, the traction system, tracks, signals, and miscellaneous facilities required in the physical construction of the entire terminal railroad ready for operation. Messrs. McKim, Mead, and White were the architects for the Station and Messrs. Westinghouse, Church, Kerr and Company executed the structural engineering work, both in the station and for the support of the streets, as well as the construction of the subways.

The station is of steel skeleton construction with masonry curtain walls, all supported by a system of columns extending to a rock foundation. This building covers two city blocks and one intersecting street, and has an area of about 8 acres. It is 774 ft. long, 433 ft. wide, with an average height above the street of 69 ft., and a maximum of 153 ft. The main waiting-room is 277 ft. long, 103 ft. wide and 150 ft. high. The Concourse is 340 ft. long and 210 ft. wide.

The level of the track system below the street surface varies from 39 to 58 ft., and is from 7 to 10 ft. below mean high water in the harbor, thereby necessitating the establishment of an elaborate system of drainage over the entire station yard area. Access to the street is gained by elevators and stairways.

[20]

To accelerate the loading and unloading of the trains, high platforms will be constructed in the station on a level with the floors of the cars, in order to avoid the use of car steps and increase the traffic capacity of the station.

There will be 21 standing-tracks at the station, and 11 passenger platforms, providing 21,500 ft. of platform adjacent to passenger trains. Within the station area, which from Tenth Avenue to the

normal tunnel sections east of Seventh Avenue comprises 28 acres, there will be a total of about 16 miles of track.

The service plant for the installation of machinery for lighting, heating, and ventilating the station, and for operating the interlocking system, is located in an independent building south of the station.

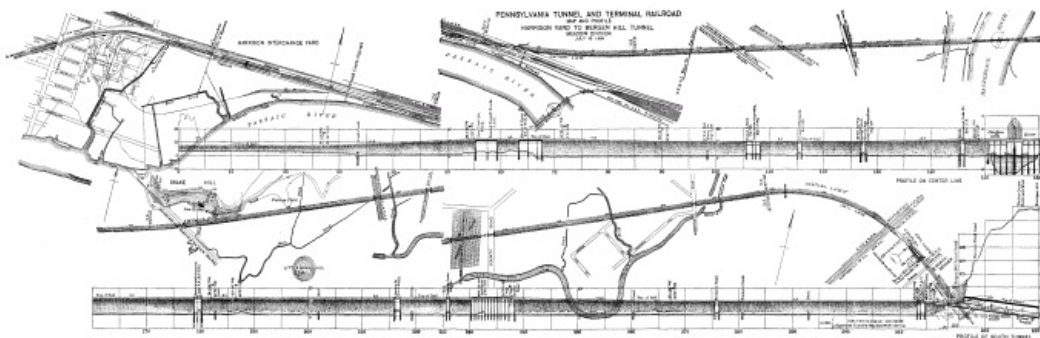
The Power-House to supply the electrical energy for the operation of the tunnel line and the Long Island Railroad is situated on property in Queens Borough adjoining the present Long Island Railroad Station near the East River, and was constructed under the Chief Engineer of Electric Traction and Station Construction. As at present designed, the dimensions of the structure are 200 ft. by 262 ft., outside measurement. It can accommodate six generating units of 5,500 kw., the standard adopted for future work, and two of 2,500 kw. for lighting the tunnels. The ultimate capacity of this station when extended will be about 105,000 kw.

*East River Division.*—Chief Engineer, Mr. Alfred Noble.

This Division begins at the eastern limits of the New York Station at a point in 32d Street, 292 ft. east of the west line of Seventh Avenue, and at a point in 33d Street, 502 ft. east of the west line of Seventh Avenue, and also includes the excavation work and retaining walls for the station site and yard, to the track level, westward to Ninth Avenue. It extends eastward from the station under 32d and 33d Streets through tunnels partly three-track and partly so-called twin tunnels to Second Avenue; thence the line curves to the left under private property to permanent shafts a few feet east of First Avenue. Four single-track, cast-iron, concrete-lined tunnels, with outside diameters of 23 ft., pass under the East River, and, after passing through permanent shafts near the bulkhead line, reach the surface in Long Island City from 3,000 to 4,200 ft. east of the East River. The tunnel portals are in Sunnyside Yard, which extends to Woodside, the easterly end of the Division, and the Yard grading with its buildings and a number of City viaducts crossing it were executed under this Division. The total length of the Division is 4.48 miles.

[21]

The total length of the entire line is 13.66 miles. There are 6.78 miles of single-track tube tunnels, and the average length of the tunnels between portals is 5.56 miles.



**Plate II.—Pennsylvania Tunnel and Terminal Railroad  
Map and Profile  
Harrison Yard to Bergen Hill Tunnel  
Meadow Division July 30 1909**

GENERAL CONSIDERATIONS.

Details have been omitted from the foregoing description, as they can be treated better and more fully by the constructing engineers in succeeding papers. There are, however, some general considerations involved in the designing of the work, which may, perhaps, be referred to more conveniently in this introductory paper, and these will now receive attention.

In all parts of the work problems were encountered requiring for their solution large expenditures and much engineering skill; but many of these difficulties had been frequently met in previous engineering experience, and the methods of overcoming them were well understood. Thus, in the Meadows Division, a long and heavy embankment, part of which was on submerged meadow land, and many bridge foundations had to be constructed; in the Bergen Hill tunnels, very tough trap rock was encountered; in the tunnels under the city, the work was much complicated and its cost increased greatly by the necessity of caring for sewers, water and gas pipes, and the foundations of adjacent buildings; and many troublesome problems were met in the construction of the tunnels connecting the East River tunnels with the Sunnyside Yard.

The novel features of the project, however, were the great tunnels extending the line under the North and East Rivers. Tunnels of the kind contemplated, to be used for heavy and rapid railroad traffic, had never been constructed through materials similar to those forming the beds of the North and East Rivers. Questions arising in connection with the design and method of construction of the tunnels will be considered later. Here they are referred to only in their relation to the location and grades of the line, in which connection the conditions controlling their establishment were the most important elements.

*Location and Grades.*—It was desirable to make the tunnels between the bulkhead lines of the rivers as straight as possible, and it was necessary to place them at sufficient depth below the dredging plane of the War Department (which in the North and East Rivers is 40 and 26 ft. below mean low water, respectively) to insure them against possible injury from heavy anchors or

[22]

sunken vessels. Furthermore, they had to pass under the piers and bulkheads of Manhattan at a depth sufficient to make it certain that they would not affect the stability of those structures. Another consideration influencing the establishment of the depth of the tunnels below the bottoms of the rivers became important as soon as the method of construction by shields with compressed air was adopted, namely, the necessity of providing sufficient cover to guard, as far as possible, against blow-outs during construction.

The tunnels under the city, connecting the sub-river tunnels with the Terminal Station, were located so as to give as favorable grades as possible. The provision of the franchise requiring the tops of the tunnels to be at least 19 ft. below the Street surface, which had been suggested by the Company to permit of future subways, had no effect on their location, as other conditions required them to be at a greater depth.

The line extending westward from Bergen Hill had to be established so as to give ample head-room at the numerous bridges over the railroads and highways which it crosses.

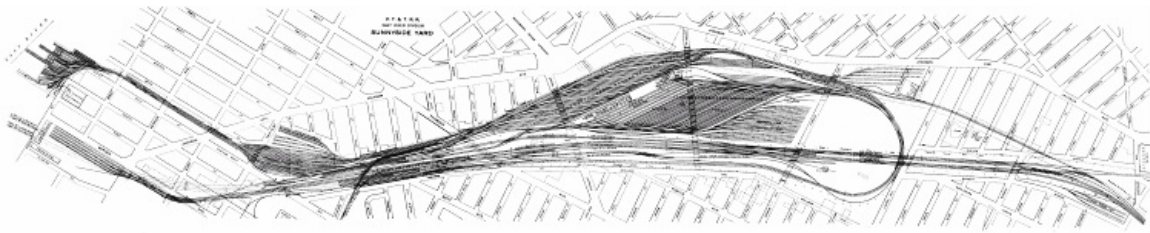
Eastward from the East River tunnels, the grades were established so as to rise as uniformly as possible to the level of the Sunnyside Yard.

The general features of the line, as finally adopted and constructed, are as follows:

The maximum grade west of the Terminal Station occurs on the New York side of the North River, and is 2% in the west-bound and 1.93% in the east-bound tunnels. The ruling grades (for the ascending traffic) being 1.32% in the west-bound and 1.93% in the east-bound tunnels. In the tunnels east of the Terminal Station the ruling grade is 1.5% for both east-bound and west-bound traffic. There is, however, descending with the traffic, a short section on a grade of 1.9 per cent. These grades would be objectionable with steam locomotives under a heavy traffic, but the development of the electric locomotive has rendered possible the operation of grades which would have formerly been considered prohibitive.

[23]

From the junction with the Pennsylvania Railroad, near Harrison, N. J., to Woodside, Long Island, a distance of 13.66 miles, there is an average of 1.5 curves per mile; the line having a total curvature of 230 degrees. The maximum curvature is 2 degrees.



**Plate III.—P. T. & T. R. R.  
East River Division  
Sunnyside Yard**

*Method of Construction of Sub-River Tunnels.*—The character of the material through which the tunnels were to be constructed differed greatly in the two rivers. The bed of the North River, at the level of the tunnels, consists of silt composed principally of clay, sand, and water, while that of the East River is formed of a great variety of materials, such as quicksand, sand, boulders, gravel, clay, and bed-rock. When the method of construction had to be decided there were no thoroughly satisfactory precedents to follow in the case of either river, although the Gas Tunnel under the East River, the partly constructed Hudson Tunnels under the North River, the St. Clair Tunnel under the St. Clair River, the Blackwall and several other tunnels under the Thames River at London, supplied much useful information. The smaller tunnels for a lighter traffic, since so successfully constructed under the North and East Rivers, had not then been completed. Under these circumstances, it was the desire of the Management that the Board should receive and consider proposed methods of construction from all available sources; and during the first year of its labors much of its time was devoted to the examination and discussion of projects submitted for its consideration by engineers and practical builders, some of these projects having decided merit. Most of the methods proposed involved temporary structures, or the use of floating plant, in the navigable channels of the river. This was objectionable in view of the resulting obstruction to the enormous river traffic. After full consideration of the subject, it was decided to adopt the shield method with compressed air for the construction of the tunnels under both rivers, this being the only method recommended by the Chief Engineers, and having the great advantage of conducting all operations below the bottom of the river, thus avoiding obstruction of the channel.

Experience has shown, as was anticipated, that it is much more difficult to construct tunnels in such material as occurs in the East River and on the New Jersey side of the North River, than in more homogeneous material such as is found in the greater part of the North River. During the progress of construction under the East River, there were frequent blow-outs through fissures opened in the river-bed, and the bottom of the river over the tunnel had to be blanketed continuously with clay, to check the flow of the escaping air.

[24]

In view of the serious difficulties which it was thought might be encountered in the application of the shield method to the East River work, other methods for the execution of this part of the project received special consideration, one of the methods considered being the freezing process. It was proposed to drive a small pilot tunnel and freeze the ground for a sufficient distance

around it by circulating brine through a system of pipes established in the tunnel. The pilot tunnel was then to be removed and the full-sized tunnel was to be excavated in the frozen material and its lining placed in position. By this means, it was intended to avoid the danger incident to the use of compressed air in material of greatly varying character. This method contained too many elements of uncertainty to justify its adoption; but as the Management considered it desirable to have, if possible, an alternative method, an extended experiment was made with the freezing process. A pilot tunnel, 7 ft. 6 in. in diameter, was driven in the bed of the East River for a distance of 160 ft., circulating pipes were established in it, and brine at a very low temperature was passed through the pipes until the ground was frozen for a distance of about 11.5 ft. around the tunnel. Observations to determine the rate of cooling and other important points connected with the process were carefully made. When it was found that the construction of the tunnels was progressing satisfactorily by the shield method, and that so much time was required to freeze the material that the freezing process could not be used to advantage in this particular case, the experiment was discontinued.

*Design of the Sub-River Tunnels.*—The sub-river tunnels consist of a circular cast-iron shell, of the segmental, bolted type, having an outside diameter of 23 ft., lined with concrete having a normal thickness of 2 ft. from the outside of the shell. Through each plate of the shell there is a small hole, closed with a screw plug, through which grout may be forced into the surrounding material. Each tunnel contains a single track. A concrete bench, the upper surface of which is 1 ft. below the axis of the tunnel, is placed on each side of the track, the distance between benches being 11 ft. 8 in. These benches contain ducts for carrying electric cables. The main reason for adopting single-track tunnels instead of a larger tunnel containing two tracks was to avoid the danger of accidents due to the obstruction of both tracks by derailment or otherwise. The tunnels are made just large enough to allow the passage of a train with perfect safety, as it was believed that with such an arrangement thorough ventilation would be secured by the motion of the trains. Experience seems to justify this assumption, but, in order to assure thorough ventilation under unusual conditions, such as the stoppage of trains in the tunnels, a complete ventilating plant will be provided for each tunnel. The rapidity and safety of construction were increased by making the tunnel as small as possible, one of the difficulties in the shield method of construction being the difference in hydrostatic pressure between the top and bottom of the shield, which increases with the diameter of the tunnel.

[25]

The concrete lining was introduced to insure the permanency of the structure, strengthen it from outward pressure and guard it against injury from accidents which might occur in the tunnel. The side concrete benches were suggested by Mr. Cassatt, President, to confine the trains to the center of the tunnels in case of derailment, and to furnish sidewalks on each side of the trains so as to obviate the necessity of walking on the track.

Refuge niches are constructed in the side benches of the tunnels. Manholes, splicing chambers, pump chambers, and other features for the handling of the electric cables and drainage, are established at intervals.

At points where unusual stresses were anticipated, as for instance where the tunnels pass from rock to soft ground, the shell was composed of steel instead of cast-iron plates. In the North River tunnels the concrete lining in the invert and in the arch was reinforced by longitudinal steel bars, but these were not introduced in the East River tunnels.

Other details connected with the structures, including the drainage, lighting, ventilation, signaling, and electrification systems, will be given in succeeding papers.

*Stability of the Sub-River Tunnels.*—One of the most important questions connected with the design of these tunnels was their probable stability under the long-continued action of a heavy and rapid railroad traffic. The tunnels are lighter than the materials which they displace even when the weight of the heavy live load is included. In the East River the character of the material seemed to justify the conclusion that the tunnels would not be displaced even under the action of the live load. In the North River, however, the tunnels are enveloped by a soft silt and it was at first apprehended that some system of supports would be advisable to carry the heavy traffic and insure the tunnels against displacement under its action. To meet this contingency, which was then believed to be a very serious one, it was proposed to sink cast-iron screw-piles through the bottom of each tunnel into and through the underlying silt until satisfactory bearing material was reached. The pile supports were worked out in sufficient detail to be embraced in the contract for the construction of these tunnels, with provision, however, for omitting them should it be determined subsequently that their use was undesirable. The contract plans contained provisions for sliding joints where the piles pass through the tunnel floor, so that the live load might be carried directly to the pile heads by a system of girders, and also for attaching the piles directly to the tunnel, the two plans being alternatives.

[26]

Investigations, made during the progress of the work to determine the physical character of the silt and its action on the tunnels, suggested the possibility that the use of pile supports might be inadvisable. This view was confirmed by actual experience in the operation of the tunnels of the Hudson Companies between Hoboken, N. J., and Morton Street, Manhattan, which were opened to traffic in February, 1908. The stability of these tunnels under traffic gave further assurance that supports were unnecessary under the North River tunnels of the Pennsylvania Railroad Company, and they were therefore dispensed with.

*Cross-Passages Between the Tunnels.*—The Bergen Hill tunnels, the land portions of the North River tunnels and the tunnels under Manhattan are connected by cross-passages at intervals

varying from 50 to 300 ft. As it was the desire of the Management to provide every arrangement possible to insure the safety of its passengers and employees and also to provide for the convenience of inspection, the question of establishing cross-passages between the tunnels under the rivers was given most careful consideration. The conclusion was finally reached that such passages as it was possible to construct between these tunnels might increase instead of diminish the danger in case of accident. No more cross-passages have therefore been constructed in the sub-river sections, except in the East River, where there is a cross-passage and pump chamber combined between each pair of tunnels about 750 ft. from the Manhattan bulkhead line. [27]

#### PROBABLE RESULTS OF THE IMPROVEMENTS.

In preceding pages reference has been made to the general objects of the improvements included in the project of the Pennsylvania Railroad Company for the New York District. While it is impossible, in this introductory paper, to analyze fully the transportation problem at New York, it seems desirable to indicate briefly some of the more obvious effects which the improvements may be expected to produce upon the distribution and handling of traffic.

New York City owes its position as the business metropolis of the country mainly to its magnificent harbor and the extensive waterfronts on its deep, wide rivers, which furnish unrivaled facilities, at a short distance from the sea, for foreign and domestic water-borne commerce, its foreign commerce being about half the total for the whole country. The water-transportation facilities of the port and its tributaries, therefore, have always been guarded with jealous care, not only by the local commercial interests but also by the General Government.

During recent years, however, the population of the metropolitan district has increased so enormously that New York is now the greatest terminal passenger and freight traffic center in the country; and in manufactures it ranks first among American cities. The new commercial interests thus created are of at least equal importance with those of the water-borne commerce, although their existence and development are largely the result of the water facilities of the port.

The local passenger and freight traffic of the Pennsylvania and of other railroads reaching the west shore of the North River is conducted by car-floats and ferry-boats which deliver their loads at piers on the Manhattan waterfront and elsewhere in the harbor. These boats obstruct and endanger the free navigation of the channels and occupy space along the waterfront greatly needed for the accommodation of the long-distance water-borne commerce, especially on the North River.

In the East River the importance of ferry-boats as a means of traffic distribution has already been greatly reduced by the construction of bridges and tunnels which provide for the greater part of the passenger and vehicular traffic. The North River, however, by reason of its greater width and the comparative slowness of its currents, is by far the more important waterway for the use of ocean-going vessels of the larger classes. In this river the conditions for the construction of bridges, within the limits of commercial convenience, seem to be practically prohibitory. Tunnels, for the transportation of passengers and the diversion of the freight traffic from the inner waters of the harbor, are apparently the only available means of relief. [28]

When the new line is in operation, a very large part of the New York passenger traffic of the Pennsylvania Railroad will be carried to the New York Station at Seventh Avenue and 33d Street and the rest will go to Cortlandt Street through the Hudson Company's tunnels. Thus a large portion of the Pennsylvania passenger ferry traffic, which amounts to more than 91,000 passengers daily, will be practically eliminated from the water-transportation problem. In addition, a large part of the Long Island Railroad's passengers will use the station at Seventh Avenue and 33d Street, and its ferry traffic will be reduced accordingly.

The new arrangements for the transfer of freight from Greenville to Bay Ridge will relieve the inner waters of the harbor of a large volume of obstructive car-float traffic. There appears to be no reason why this traffic should not be eventually conducted through tunnels under the outer harbor, should future transportation conditions justify the enormous cost of such structures.

It is to be remarked that while these new arrangements greatly reduce the passenger and freight water transportation, they have no effect on the large vehicular traffic across the North River which must continue to be conducted by ferries until it can be otherwise provided for. As long as these conditions exist, ferry-boats must be used in large numbers and continue to obstruct the North River. This difficulty probably cannot be overcome by the construction of bridges, as in the case of the East River, but it does not seem too much to expect that, eventually, tunnels to provide for the vehicular traffic, like the Blackwall tunnel under the Thames, will be established under the North River.

It would be interesting to estimate the increase in railroad traffic capacity resulting from these improvements, but the data required for this purpose are not available. Some idea of the increase in passenger traffic capacity resulting from the establishment of the tunnel line may be obtained by comparing the proposed daily train-movements for the new station with the train-movements at other important railroad stations. The daily train-movements of six such stations are given in the following table: [29]

Total trains in and out for	Movement at maximum
--------------------------------	------------------------

	24 hours.	hour.
Jersey City	281	29
Broad Street Station, Philadelphia	538	48
Union Station, St. Louis	462	89
South Terminal Station, Boston	861	87
Grand Central Station, New York	357	44
Pennsylvania Station, New York <sup>[B]</sup>	500	50

The freight capacity of the Pennsylvania System at New York has been greatly enlarged by the construction of the Greenville Yard and the facilities connected therewith, but it is impossible to estimate the amount of this increase. However, it is worthy of remark that, during the period from 1900 to 1906, the freight traffic density on the directly-operated lines of the Pennsylvania Railroad Company increased from 3,268,330 to 4,742,081 ton-miles per mile of road, a growth of nearly 50 per cent. Doubtless the improved freight facilities of the New York District had a large influence in the development of this increase.

One of the most interesting points connected with this development of traffic facilities is its influence on the relative distribution of population in the different parts of the metropolitan district. In 1907 the population per acre of the different divisions of Greater New York was reported as follows: Manhattan, 157; Brooklyn, 29; Bronx, 14; Queens, 3; Richmond, 2. The effect of new lines connecting some of these districts, and sections of New Jersey not far from the North River, with the business center of the city will undoubtedly be to increase greatly their population-density. It does not seem probable that the population-density of Manhattan will be sensibly reduced by these improvements, for they stimulate the increase of population, and apparently no increase of transportation facilities can keep up with the growth of the city. The population of a great commercial city must be congested near the business center. This is a necessary condition of its existence. All that can be done to meet this condition is to provide all possible facilities for moving the people into and out of the business districts and within its limits.

[30]

During recent years the business population of the lower part of the Borough of Manhattan has become greatly congested. Very high buildings, providing business accommodations for large numbers of people, have been constructed, and these people must move to and from their working places at about the same times, that is, at the "rush hours" in the morning and afternoon, at the beginning and ending of the working day. Every effort has been made to provide for this immense and rapidly increasing local passenger traffic, by the construction of surface, elevated, and subterranean railways; but the demand for transportation has increased much faster than the facilities can be provided, and it is evident that the limit of down-town passenger traffic facilities has been very nearly reached.

Apparently, the only remedy for these conditions is the movement of business and the people transacting it up-town or to the Boroughs of Brooklyn and Queens, which are now readily accessible by tunnels and subways. This movement, of course, is resisted by the great real estate and money interests centered in the lower part of the city, but, notwithstanding this resistance, the improvement has commenced and has rapidly advanced. The great retail houses are being established above 23d Street; the banks and brokers' offices are rapidly appearing around the new business center of the city. The facilities afforded by the telephone and the subway for communication with the money center have doubtless greatly promoted this up-town movement.

When the Pennsylvania Tunnel Extension is in operation, the easiest and quickest way for the passenger to reach the city from Newark will bring him into the Pennsylvania Station at Seventh Avenue and 33d Street. The schedule fast time from Newark to the New York Cortlandt Street Station is now 25 min. This may be reduced to about 18 min. by the use of the Hudson Company's tunnels, and while this involves inconvenience in changing transportation at Jersey City, yet it brings the traveler three blocks nearer Broadway. The time from Newark to the Pennsylvania Station will be about 17 min., and the trip will be made without change of transportation, so that, undoubtedly, by far the greater part of the Pennsylvania's passenger traffic desiring to reach the shopping and hotel center of the city will go to the new up-town station.

[31]

The effect of the Tunnel Extension in increasing the volume and rapidity of the up-town movement and the real estate values will be very great; indeed, its influence is already apparent, although the line is not yet opened for traffic. With the extension of the present subway down town on the west side with direct connections to Brooklyn, and up town from 42d Street to the Bronx, with connections to permit convenient transfers between these two straightaway subways—one on the east side and the other on the west side of Manhattan—the Pennsylvania Station will become a great center for receiving and distributing passenger traffic between all the Boroughs of the City and outlying points. The new post office to be established adjacent to the Terminal Station will also greatly assist in accelerating the up-town movement.

In concluding this account of the New York Tunnel Extension project, the writer desires to pay a tribute of admiration and respect to the memory of the late A. J. Cassatt, President of the Pennsylvania Railroad Company, to whom the conception, design, and execution of the project are mainly due. His education and experience as a civil engineer, his thorough knowledge of all the details of railroad construction, operation, and management, gained by long and varied service, the directness, clearness, and strength of his mind, and his great executive ability, placed him at the head of the railroad men of the country. In the consideration of great problems, whether of transportation, finance, commerce, or political economy, he was almost unequaled,

owing to the breadth, originality, and decisiveness of his character; yet his manner to his subordinates was so direct and simple that he seemed unconscious of his own superiority. Great as it is, the New York plan of improvement is only one item in a far-reaching scheme of development which became the policy of the Pennsylvania Railroad Company through Mr. Cassatt's advice and influence, yet his strongest interest was doubtless centered in the New York works. It is the sincere regret of all connected with the design and execution of the project that he did not live to see its completion.

#### FOOTNOTES:

- [A] Brigadier-General, U. S. Army, *Retired*; Chairman, Board of Engineers, Pennsylvania Tunnel and Terminal R. R. Co.
- [B] Proposed train service when Station is opened, the ultimate capacity of the Station being in excess of 1,000 trains per day.

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