Shall We Have Bridges or Tunnels?*

Past Experience Furnishes the Answer

By G. F. Kunz

In dealing with the tunnels in operation at the present day in connection with the great railroad terminals of New York city it was observed[1] that in no case was provision made for any other use of the tunnel than for railway traffic. "The great volume of traffic that does not and cannot use the railways must still cross the Hudson by ferry alone. This state of things cannot continue long, now that railroad tunnels have been successfully constructed and the method is shown to be so possible."

In the present article the writer will briefly review some of the schemes proposed for traffic tunnels under the rivers, and also for subway routes to connect them with each other and with the principal thoroughfares.

In the first place, we may note that this latter idea has already been carried out on the New Jersey side of the Hudson, in the subway of the McAdoo system already described, connecting the several railway termini and the river tunnels. Something of the same kind will surely be needed on the Manhattan side—a subway near and parallel to the river. But of this, more will be said later.

The congestion of the business streets and of the waterfront by vehicles of all kinds carrying freight has reached a point where it has become very serious, and threatens to restrict the further development of commerce at this port. Besides the railway terminals, some of the most important steamship lines now dock on the New Jersey side, and hence vast amounts of freight must be taken over the ferries both ways, and handled on both sides of the river to load and unload. The cost and the delays involved by these conditions are enormous, the former alone rising into many millions annually.

To meet this grave necessity for relief there has been proposed by Mr. C. Wilgus—a leading engineer connected with the New York Central Railroad system—and laid before the Public Service Commission,[2] a plan consisting essentially of a subway road for the carriage and delivery of freight along the waterfront. It is proposed to have branches beneath the main business streets, and a belt line under South and West Streets, the latter connecting with the New York Central yards at West Sixtieth Street and with tunnels under the Hudson and East Rivers, and so with the opposite water-front on each. The freight is to be carried on these roads in cars of standard gage, which thus can run directly into the yards or stations of any connecting railroad for reception or delivery. There will also be tracks leading out on the principal steamship piers. The larger transfers of freight are to be made at points distant from the crowded parts of the city; and the subways are planned on a scale to handle nine tenths of the freight that is now slowly and laboriously carted through the streets. The scheme also contemplates an elevated railway for passengers in the space over the belt tracks, in the river-front streets relieved of their present congestion. The project is a most elaborate and extensive one, but is very carefully and skillfully wrought out.

Another plan is to construct a passenger subway parallel to the river fronts, connecting with new tunnels at several points, as well as with the railroad tunnels already built, and also with the existing subway lines at the various stations. This would be a reproduction on a greater scale—and with transverse branches to connect with the present subways—of the McAdoo line on the New Jersey side.

Whatever system shall be adopted, however, for passenger and freight distribution in the city, we are brought back to the problem of tunnels beneath the Hudson; and here some interesting and important questions arise as to the manner of their construction.

All the tunnels before described have been circular tubes, excavated essentially by a process of simple boring. Indeed, it is said that Mr. Greathead, the inventor of the "shield" method that bears his name and has been used in almost all the work herein described, derived his idea of the iron "shield" for tunnel construction from the method by which the boring mollusk, Teredo (commonly known as ship-worm) makes its tubular burrowing in timber, protected by its small cylindrical shell in front, and lining the tube as it proceeds, with a calcareous coating.

This form of tunnel has some disadvantages, however. If enlarged sufficiently to take two tracks, or roadways, much waste space remains above and below them. The Pennsylvania tunnels are 23 feet in diameter, and are lined with 2½ feet of concrete, leaving 18 feet of clear width. A slight enlargement would allow room for two roadways for vehicles, and a footpath. Such a tunnel could be built, according to Mr. Davies, the engineer who constructed the East River tunnels for the Pennsylvania road, at a cost not exceeding $3,000,000 a mile—about the length necessary for the Hudson. But a further enlargement would afford much greater advantage p oportionately in regard to space. The latest proposition is one made by Messrs. Jacobs and Davies, for a Hudson tunnel of 31 feet diameter outside and 28 feet 9 inches within, to accommodate four roadways, two above and two below, with a footpath on each side of the upper level. The tube is divided at its middle by a horizontal partition of concrete; above this are two roadways for slow traffic—trucks, vans, etc.—12 feet high and 9 feet wide; and below it are two roadways for rapid vehicles—automobiles, etc.—9 feet high and 8 feet wide. The concrete lining, somewhat as in the Pennsylvania Railroad tubes, is carried up vertically to the partition; above this is a footway in the semi-arch on either side, of 4 feet 6 inches width, alongside of the truckway; beneath this is a passage or gallery in the concrete filling, for pipes, electric wires, etc.; and provision is made for air-passages and drainage in like manner. The whole is a most complete and systematic plan, and seems admirably adapted to meet the requirements of such a tunnel, with remarkable economy of space.

Another tunnel has been built, however, in a wholly different manner—that beneath the Harlem River at One Hundred and Forty-fifth Street, for the Rapid Transit Subway. This was constructed by Mr. Duncan D. McBean, and he has proposed to the Public Service Commission to use the same method for tunneling the Hudson and East Rivers, with certain advantages of construction over the tube form, and at less expense. The Harlem River tunnel was built without any mishap, and has served its purpose perfectly. Can the same process be applied to the Hudson?

The McBean method is essentially the following: A wide trench is dredged in the river-bed to about half the depth of the tunnel, and walled off from the water with timber casing. The upper half of the tunnel is built outside, in semi-cylindrical segments; and these are lowered into place one by one. The ends are closed by temporary partitions so as to make the upper half serve as a work-chamber, in which compressed air can be used, while beneath, the lower half of the tunnel is excavated, and then lined with concrete. Later, concrete and filling are added externally, the trench filled up and the cross-partitions and outside casing removed. In this method, the tube is not of necessity a cylinder; and two or several roadways may be built side by side, without increasing the height; while two side-walls only are necessary for the whole to withstand the external pressure—the several roadways being separated simply by partitions or bracing. The whole rests upon a strong foundation of piling, driven from the trench to rock.

This last statement carries with it the entire case, as regards the Hudson. The plan worked well in the Harlem River, where the rock lies at very moderate depths; but it is needless to repeat here what has been already emphasized in this article—as to both piers for bridges and pile-work for tunnels—that the depth to rock in the Hudson is prohibitive for either.

In Mr. McBean's proposal to the Commission, after describing the advantages of his method and its successful application to the Harlem tunnel, he offers to construct several tunnels of 100 feet wide, giving two double roadways—one for trains and one for automobiles—four car-tracks, and a footway, all side by side, with an interior height of 18 feet. The cost for any of these tunnels, he specifies as $1,000 per foot of length.

After reading this account, and examining the careful drawings that illustrate the plan, it is very disappointing to recognize the fatal difficulty in the way. In a published letter to the Mayor of New York (September 19, 1910), as to a proposed new tunnel under the Harlem River, Mr. McBean says that in his method "the pile foundation is an integral part of the structure (which cannot be omitted in soft ground), thus insuring the integrity and permanency of the foundations at every point." (P. 5.)

Still another method has been used, at Detroit, Mich. In this, which is known as the Wilgus, or Trench method, some of the features of the last are united with the tube form. A trench is dredged, to the full depth of the tunnel, and into this are lowered sections of iron tube which are joined on to each other to form a roadway or track-way. Several such tubes may be laid nearly side by side, with bracing between; and when finished, the whole lower part of the trench is filled with concrete, encasing and embedding the tubes, beneath, around, and above. The concrete is laid under water, through pipes, under the supervision of divers. This method gives a very solid concrete structure, enclosing the iron tube-ways. All these are on one level, as in the McBean system. The Wilgus method has been proposed for the new four-track subway tunnel under the Harlem River, but we are not aware that it has been suggested for the Hudson. It is possible that such a firm concrete structure might dispense with the pile foundation. In calling for proposals for the new Harlem tunnel, the Public Service Commission have not positively required this feature in a structure of the Wilgus type, but have left it optional, apparently with the view that, as in the Pennsylvania Railroad tunnels, a foundation is not essential to stability. In that case this method might be applicable to the Hudson; but the dredging of a wide trench to the necessary depth, with all the crib-work, etc., requisite, would be a matter of great difficulty and great cost, in a river so broad and deep.

One other suggestion may be noted here, as bearing on the Hudson problem. Mr. Alexander E. Dandridge, in a recent letter, has taken the ground that engineers in general have erred in assuming that they must accept whatever kind of material Nature has provided in a river-bed, and penetrate it as best they can. He advocates instead the formation of an artificial bed, through which a tunnel can afterwards be bored. His plan is to use crushed traprock, mingled with a suitable proportion of stiff clay to give it firmness and coherence. This he would dump from scows into the river for a space several hundred feet wide and bring it up to near the surface, from the shore outward for a thousand feet. The weight of this load would press the lower portion of the mass into a very compact condition. Then the upper part would be dredged off, leaving a water depth of say fifty feet, and the material dumped onward for another thousand feet, and the same process repeated until a basement of this kind had been laid across the whole distance. Then, through this submerged causeway, as it might be called, the tunnel would be made by boring, with a firm stiff bed and wall instead of the loose river silt.

This suggestion is ingenious, and seems at first sight very feasible. The question would be, however, as to such a dense mass retaining its position amid and upon the silt. A causeway or embankment built across swampy ground is liable to settle, sometimes even causing the ground to rise in ridges parallel to it, at considerable distances. On land, where the road or track is on the top of the causeway, repairs and addition are easy; but in a tunnel enclosed within such a causeway, and beneath a deep river, settling would be a very serious matter. This question is probably impossible of determination save by actual experiment, and after considerable time; and this uncertainty seems to bar the way to Mr. Dandridge's well-reasoned scheme being attempted.

The tube-method, however, has already been used with apparently complete success, in the river bottom as it is; and if no tendency appears to settling or other weakness in the railroad tunnels, with their extremely heavy and rapidly-moving trains, none need be feared for tunnels used for ordinary traffic and for the slow carriage of freight. The objection as to waste of space in a circular tube has been eliminated in the Jacobs-Davies plan of a two-story tunnel, above described; and there seems no reason to doubt that ere very long the Hudson River may be traversed by several tunnels constructed on some such plan. If these should then be combined with a freight-subway in the city, such as the Wilgus system proposed, or something similar, and with the existing subway for passenger travel, a very comprehensive scheme would be developed, for the relief of the congestion that has now become so serious, and for the further development of the metropolis of America.

London is now traversed by a great connected system of subways and river tunnels, amounting to a total of many miles, and now approaching completion after years of experiment and construction. New York will surely be similarly provided in the near future.

The first Thames tunnel, between Rotherhithe and Wapping, was planned by Marc Isambard Brunel. A shield of timber having several independent sections was used. The work was begun in 1825 and completed in 1843, the cost being about £1,300 per linear yard. In part this tunnel was carried through almost liquid mud.

* Reprinted from Appendix B of the Eighteenth Annual Report of the American Science and Historic Preservation Society.

1 Scientific American Supplement No. 1979, page 370.

2 Scientific American, vol. xcix., No. 23, December 5, 1908, page 413.

The Blackwall tunnel, for which Sir Alexander Binnie was engineer, is 3,116 feet in length by 24¼ feet interior diameter. In this case the passage was made through clay and about 400 feet of water-saturated gravel. Operations were begun here in 1892, the work being finished in 1897. The third and largest of these Thames tunnels, that known as the Rotherhithe tunnel, has a cross-section larger than that of any other similar construction. Maurice Fitzmaurice was the engineer and designer of this tunnel, which was carried through sandy and shelly clay overlying a seam of limestone resting upon a stratum of pebbles and loamy sand; for 1,400 feet it runs directly under the river bed. Four years were required for its completion, from 1904 to 1908.

Of the two later constructions, the Blackwall tunnel measured 4,470 feet from portal to portal (6,200 feet between grade points), the tube has an external diameter of 27 feet and an internal diameter of 25 feet 4 inches; through it runs a roadway 16 feet wide and 17 feet 7½ inches high at center, and two foot-ways each 3 feet 1½ inches in width. The corresponding dimensions for the more recently built Rotherhithe tunnel are: length from portal to portal 5,200 feet (between grade points 6,883 feet); roadway 16 feet wide with a height at centre of 18 feet 6 inches; two footways each 4 feet 8½ inches wide. The number of vehicles that passed through this tunnel in 1911 was 896,629 and in 1912, 973,336; the volume of traffic through the Blackwall tunnel is stated to be nearly as large.[3]

In some of the tunnel plans it has been proposed to do away with the difficulty of approaches, which involve a great expenditure of space, by a system of elevators. The tunnel would terminate at the actual river-front, in a spacious chamber, in which would be installed elevators large enough to take vehicles of any size up and down between the tunnel and the street-level. Something of this kind wil undoubtedly be a feature of the new tunnels for automobiles, carriages and freight.

That it is perfectly practicable to construct a large tunnel at a relatively small outlay is shown by estimates submitted for such a tunnel, to be built on the McBean method. Here elevators placed at the bulkhead line at each termination would lower and raise cars, vehicles and pedestrians, to and from the tunnel. The entire width of the whole structure would, as we have already stated, be about 100 feet, and the total cost of building such a tunnel between Manhattan Island and the New Jersey shore would be about $5,000,000.

The great difference in the expense of maintenance must also be considered in comparing the total expenditure for a bridge with that entailed by the building of a tunnel. The up-keep of a cement-like tunnel would be almost nominal, whereas the cost of a bridge, with its tendency to rust, the cracking of bolts, etc., is enormous. One single item of expense for the Queensboro Bridge, the painting of the structure, amounted to $33,000.

The cost of building a bridge would be from ten to twenty times as great as that of tunneling the river; and as we can now estimate closely both the time and the expense required for the construction of a tunnel, we can safely assert that within a comparatively short period there could be three or four large enough for traffic, special ones for automobiles, and also others for railroads. A notable advantage would be that these various tunnels could be located at a number of different points along the river, at Fifty-ninth, Eighty-sixth, Ninety-sixth, One Hundred Tenth, One Hundred Thirtieth, One Hundred Thirty-seventh, One Hundred Fifty-seventh, and One Hundred Eighty-first Streets, to connect with the main thoroughfares and subways—thus satisfying the requirements of those who have advocated these different sites for the construction of a bridge, and who have been forced to agree upon a single site. There is little doubt that we could have a double tunnel at each and every one of these streets for the cost of one bridge.

In making any of these improvements, however, one thing should always be borne in mind, the necessity of preserving intact, as far as possible, the beauties of Riverside Park, one of the great ornaments of our city. Hence the laying of surface tracks and the establishment of extensive freight-yards within the boundaries of the park should be avoided. All the requirements of the railroad can be satisfied and the park preserved by placing the tracks under cover, and to this there can be no objection. The successful operation of our subway transporting under comfortable conditions 1,200,000 passengers daily, renders any objection to underground means of transit certainly unreasonable, especially as all trains within the greater metropolis will certainly be and should be operated by electricity An important consideration in favor of this plan is the fact that it would remove all danger of injury from passing trains to anyone not immediately connected with the operation of the railroad, as only employees of the railroad would be permitted to have access to the subway; moreover this provision would also do away with the petty thieving now possible. An ideal plan, and a perfectly feasible one, would be to lay the main freight tracks on the Jersey side of the river, where within a comparatively short distance of the river front land can be acquired at a very reasonable cost. Tunnels could then be built across the river at points in a line with St. John's Park, Thirtieth, Street, Fifty-ninth Street, Seventy-second Street, and One Hundred Thirtieth Street, conveying the freight directly to these distributing points, the main yards to be on the Jersey side. For a two-track road running from Fifty-ninth Street to Two Hundred Tenth Street, the New York Central Railroad now occupies about thirty acres of ground or forty-five acres for a three-track and sixty acres for a four-track road. And they are much hampered for lack of proper freight yard facilities. It would not cost much to purchase an area of 3,000 or 4,000 acres in the Jersey meadows. This, to say nothing of the obligation which ought to rest upon any truly representative corporation, to respect and preserve one of the greatest heritages of New York city, the banks of the noble and beautiful Hudson.

In the report of the New York State Bridge and Tunnel Commission submitted to the Legislature in April, 1913, the commissioners favor the construction of tunnels instead of a bridge. This preference is based on the drawbacks of the proposed bridge apparent from a consideration of a tentative plan proposed by Boller, Hodge and Baird, consultant engineers to the Commission. As the opinion prevailed that the neighborhood of Fifty-seventh Street would be the best point for the New York end of the proposed bridge the estimated length of the main structure and its approaches refer to a bridge constructed there. The entire length, including approaches, from Ninth Avenue and Fifty-seventh Street, Manhattan, to the Boulevard in Weehawken would be 8,330 feet, and the great central span would measure 2,730 feet in length between pier-head lines and 2,880 from one tower center to the other. Accommodations would be afforded for eight lines of rapid transit trains, as well as for two driveways, each thirty-six feet wide, so that four vehicles could travel abreast, and also for two footways, each eight feet in width. The supporting towers would rise to the unexampled height of 745 feet from bed rock, but 239 feet less than the height of the Eiffel Tower. In view of the altogether exceptional character of the structure, the eventual cost would probably greatly exceed the original estimates, and hence even the large sum of $42,000,000 given by expert engineers may be much too low. There is, therefore, every reason to commend the present preference of the commission for tunnels, two of which would cost but $11,000,000, and the changed attitude of the members in this respect from that assumed a few years since proves that they were open to conviction and impartially anxious to recommend the course best calculated to further public interests and welfare.

Not only would large tunnels of this type aid most powerfully in the development of the commercial interests of lower Manhattan, at the same time helping largely to relieve the present congestion, daily growing worse, but it has been figured that they might bring in a very satisfactory percentage on the money invested in them. Putting the annual interest charges on capital at $550,000 and the yearly cost of maintenance at $90,000, we have $640,000 to be provided for. Should 5,000,000 vehicles use the tunnels in the course of the year, as is indicated by the volume of ferry traffic, and should the average toll be received as is now collected by the ferries (about 24 cents per vehicle) there would be an annual revenue from this source of $1,200,000, showing a profit about equal to the amount of the interest charges.[4]

The legal status of the land beneath the Hudson has been partially defined in a recent decision by Supreme Court Justice Arthur S. Tompkins. He was called upon to determine whether the New York Central Railroad Company could condemn land under water near Peekskill which the company wished to fill up so as to straighten out their tracks and enlarge the road here in establishing the projected four-track system to Peekskill. Several private owners laid claim to this sub-aqueous land under a charter granted June 17, 1697, by King William III to Stephanus Van Cortlandt, and it was also contended by the Attorney-General that as the State held the land under water in trust for the people, such lands could not be acquired from it by a corporation. However, Judge Tompkins decided against this latter contention, holding that where there was proof that the land was necessary for railroad purposes it might be acquired for this use, noting that in case of an attempt to acquire all the lands under the river—a contingency suggested in the Attorney-General's brief—the claim could be successfully resisted with the argument that no legitimate railroad use could require the entire river bed of the Hudson or any other river.

A comprehensive plan for the improvement of the facilities for freight handling on the west front of New York city has been proposed by D. C. Willoughby, of Boston, and submitted to the consideration of the Board of Estimate. Although the requisite capital, estimated at $85,000,000, would be provided from private sources, the title to the subway, warehouses and and tunnels projected, would be from the outset vested in the city, only the equipment being regarded as the company's property; the latter also would be accorded a twenty-five years' franchise, with one renewal for a like period.

The plan provides for the construction of a six-track subway, running beneath a marginal way along the river front from Cortlandt Street to Twenty-third Street, two of the tracks being brought into connection at this point, by means of a cross-over, with the New York Central's tracks. The other four tracks would connect with a freight tunnel to be carried beneath the North River at about Twenty-third Street, passing out into a freight classification yard in New Jersey. Above the marginal way, on the New York side of the river, immense warehouses would be erected, one for every four blocks, in which space could be rented by merchants in the neighborhood for the reception of freight consigned to them. It would thus be possible, after proper classification of the freight in the New Jersey yard, to transmit by mechanical means the lots consigned to each merchant directly to the warehouse wherein he had reserved space, obviating the necessity of long cartage from a distant point to the merchant's place of business. There would also be a small classification yard in Manhattan for the distribution of fractional parts of a carload. Should this plan be put in operation it is estimated that as many as 2,642 cars could be loaded or unloaded simultaneously. Of the $85,000,000 to be expended in all, the Manhattan subway would cost $16,486,000, and the warehouses, the subsidiary yards, etc., in Manhattan, $25,000,000, making a total of over $40,000,000 to be expended within that borough.

In St. Louis it has been found practicable to run complete freight trains through a tunnel into the basement of the building occupied by a great hardware firm. The cars, loaded with consignments from the manufacturers, are here divided into so many different groups and labeled to the different firms to which the hardware is to be shipped, whether a single carload, five carloads, or ten carloads, no unloading and reloading being requisite.

A proposition for a four-tube, or a six-tube tunnel under the East River has been submitted by Duncan D. McBean to the consideration of the Public Service Commission, with the claim that a four-tube tunnel of this type could be built for but 50 per cent more than the cost of one of the three two-tube tunnels to be constructed on the shield method as proposed by the Public Service Commission. Two of the four McBean tubes would constitute a roadway 39 feet in width and 15 feet 9 inches in height. A marked advantage over a tunnel built on the shield method would be a lesser depth, 65 feet beneath the river surface instead of 95 feet, thus considerably shortening the necessary approaches, which might be made to begin respectively at Broad Street, Manhattan, and Montague Street, Brooklyn. Should a six-tube tunnel of this type be constructed, Mr. McBean suggests that two of the tubes be used by the Interborough Broadway subway line and two by the Brooklyn Railway, leaving the present tunnel under the East River for the Seventh Avenue subway line.

A further extension of one or more of the traffic tunnels may also be considered, viz., that instead of terminating at or near the river-front, on the New Jersey side, it should be continued westward under the Palisade ridge, so that traffic of all kinds could pass through the hill and have access to roads in the open region beyond. This, it will be remembered, is the case already with the tunnel of the Pennsylvania Railroad, which emerges at some distance west of the Palisades. As with that one, there should be of course also a north and south connection near the river, for vehicles and freight; but a continuation beneath the ridge would open up large added possibilities.

As a recognition of the growing sentiment in favor of tunnels we may note that by chapter 189 of the Laws of 1913, the name of the New York Interstate Bridge Commission was changed to that of the New York State Bridge and Tunnel Commission.

[3] To the New Jersey Interstate Bridge and Tunnel Commission, a Presentation in the Matter of Tunnels or Bridges for Highway Crossing of Hudson River, by Jacobs & Davies, Inc., Feb., 1913, p. 12.

[4] To the New Jersey Interstate Bridge and Tunnel Commission, a "Presentation in the Matter of Tunnels or Bridges for Highway Crossing of Hudson River," by Jacobs and Davis, Inc., February, 1913, pages 5, 6, 9.

A Lead-Sodium Alloy

Metallic sodium hardens lead without changing its color. Two per cent of sodium will harden lead so that it will ring when struck; a larger amount causes it to become brittle. The lead-sodium alloy is sometimes used as a bearing metal. One of the bad features of the alloy is that it corrodes rapidly in damp air or in contact with water.—*English Mechanic and World of Science.*