Spring 1997

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By Kurt C. Schlichting

In 1903, the New York Central Railroad began construction of a terminal at 42nd Street in New York City—the new "Grand Central." Besides the new station building and a double-tier underground yard, the railroad also planned to develop "air rights" over the yard and, most crucially, to switch from steam to electric power for all passenger service in Manhattan and throughout the Bronx and Westchester County. The total effort would represent the largest single construction project undertaken thus far in any American city. As it was entirely premised on the introduction of electric power in place of steam, the railroad's plan provides a fine case study of the role of the "visible hand" in the application of a new technology to a major transportation system.

There have been a number of theories developed to explain how new technologies find application in society. William F. Ogburn argued that technological innovation was a social dynamic "largely independent of the thoughts and actions of individuals."[1] Rather, it was a broad social process: At any one historical moment, if one inventor had not developed a new technology, someone else would have. Ron Westrum, to the contrary, considers technological innovation the result of a series of deliberate choices and decisions made by individuals, a process he labels, after Alfred Chandler, the "visible hand." "With different decisions," Westrum writes, "we get different directions for society."[2]

Chandler, the leading historian of American business, first coined the term Westrum used later in the title of his seminal 1977 book, *The Visible Hand: The Managerial Revolution in American Business*, to describe innovations in management structure after the Civil War—innovations that enabled the business corporation to evolve and operate on a vastly expanded scale. A new class of professional managers emerged who were committed to technological change and who developed a corporate structure that facilitated the introduction of new technologies. The visible

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hand was so successful that ultimately the very idea of progress became focused on technological change. Merritt Roe Smith and others argue that the pervasiveness of technology and its impact on society in the years after the Civil War has meant that the history of our own century is essentially the history of technology.[3] Grand Central serves as a prime example of the visible hand in action. The individuals involved in the project made a series of complex decisions with far-reaching consequences not only for the New York Central but also for the development of midtown Manhattan.

Grand Central has not received the serious attention from historians that it deserves. More than fifty years ago David Marshall published a book focusing on personalities, which provided a wealth of anecdotal detail.[4] William D. Middleton's book on Grand Central, written for a general audience, includes many photos documenting the construction and functioning of the new terminal.[5] And the Municipal Art Society of New York issued a collection of essays examining the station in an architectural and historical context.[6] None of these works considers the role of technology in any detail, however, and that is what I propose to do in this article.

Interrelated Problems

The New York Central faced a complex set of problems with its rail and terminal facilities in New York City, especially around its 42nd Street station. The first Grand Central, constructed in 1871, included a cast-iron and glass trainshed with seventeen passenger platforms. When opened it was the largest station in the United States, used by the New York, New Haven & Hartford and the New York Central–controlled Harlem River Railroad as well as the NYC itself. Within a decade, however, traffic was straining the station's capacity, and in 1886 seven more passenger platforms were added. But this alleviated congestion only temporarily. At the turn of the century *Scientific American* warned that "radical changes must be made in this terminal or the traffic within the next few years will be thrown into a condition approaching deadlock."[7]

A second problem involved the yard stretching from 44th Street north to 58th Street. There was simply not enough trackage to service and store all the cars and locomotives needed to handle the traffic at Grand Central. Moreover, this yard created a physical barrier that divided Manhattan's upper east side in half. William J. Wilgus—who, as the NYC's chief engineer, was the individual most directly responsible for the innovations eventually implemented at Grand Central—clearly recognized the negative impact. He called the yard a "veritable 'Chinese Wall' to separate the city into two parts for fourteen blocks . . . and force the discontinuance of a leading north and south thoroughfare, then known as Fourth Avenue [Park Avenue]" and asserted that it presented "almost insuperable obstacles to normal urban traffic."[8] Although footbridges and viaducts did pass over the tracks, the noise, steam, and dirt discouraged all but the most hardy from crossing.

And there was more. Between 58th and 96th streets the tracks into the station had first run in an open cut. This had been roofed over by the turn of the century, and, despite vents for steam, soot, and heat, conditions inside were appalling. Criticism from the press was unrelenting. For example, a 1900 editorial in the *New York Times* lamented what passengers had to endure on Labor Day: "Trains came in from one to two hours late and spent from half an hour to an hour in giving their passengers Turkish baths in one of the side tunnels where they turned on them a heat conservatively estimated at 150 Farenheit."[9] There was one final precipitating event. On January 8, 1902, a train from Danbury was stopped in the tunnel at 56th streets. The tunnel was choked with smoke and steam, and, despite warning lights and signals, the Danbury train was rear-ended by one from White Plains, killing fifteen passengers and injuring scores more. Reaction was fast and furious. The engineer of the White Plains train was indicted for manslaughter, and the press demanded that NYC officials also be indicted. To force change, on May 7, 1903, the state legislature prohibited the use of steam locomotives south of the Harlem River or anywhere in the tunnel after July 1, 1908. The NYC had to make some big choices.

Just when the NYC was beginning work on the new Grand Central, the Pennsylvania Railroad, its arch rival, announced plans to build its own passenger station in Manhattan at 34th Street and Seventh Avenue. The PRR, though considered to be the best-managed railroad in the country, had lagged behind the NYC in competition for passenger traffic between New York and Chicago because of its lack of direct access to Manhattan. Its trains ended their journey in Jersey City, and passengers then boarded ferries to cross the Hudson River. Because of this inconvenience, most travelers preferred the NYC.

But that situation was about to change. In 1900, the PRR purchased a controlling interest in the Long Island Rail Road, whose commuter lines ended at the East River in Queens. To bring passenger trains from both east and west directly into Manhattan, the company planned several tunnels, two under the Hudson, two under the East River, and one under Manhattan Island itself at 32nd Street. When these tunnels were completed along with Penn Station, the PRR would clearly pose a more serious competitive threat to the NYC than ever before.

Radical Solutions

The multiple problems faced by both the NYC and the PRR demanded radical solutions. If the Central were to persist in using steam locomotives, it would have to abandon its 42nd Street terminal, an extraordinary asset in the heart of the nation's leading city. Similarly, what the Pennsylvania planned would be impossible with steam. Wilgus, then a NYC vice president, understood that electrification was the key. But not only did he have to understand the nature of the solution, he also had to persuade the officers and directors to proceed with a plan requiring an enormous commitment. Historian Carl Condit summarized the situation faced by the railroad and the critical role played by Wilgus:

> It was clear scarcely after the turn of the century that no amount of enlarging, rearranging, and embellishing of Grand Central Station would offer any more than a brief palliative for meeting overwhelming needs. If the task of accommodating Grand Central's traffic was to be undertaken at all, it seemed inescapable that the owners would have to begin all over again. The chief proponent was William Wilgus, who must have been remarkably eloquent in persuading his employers to spend vast sums on monumental enterprises.[10]

Wilgus recognized that there was a linked set of problems. The railroad owned only a limited amount of property at 42nd Street. His solution to the problem of limited capacity was to expand vertically—to build two terminals, one over the other. Long-haul service would be accommodated on the upper level while commuter service would use the lower. Wilgus wrote, "Why not tear down the old building and train shed and in their place, and in the yard to the north, create a double-level, undersurface terminal on which to superimpose office quarters and revenue producing structures made possible by the intended use of electric power?"[11]

Of course, a two-tiered underground terminal and train yard would be impossible if steam power were to continue in service. In 1901 and 1902, however, when Wilgus was formulating his plan, no electric locomotive had yet been developed that was capable of hauling the heavy trains that moved in and out of Grand Central. Electric power was used for street railways and had recently been introduced on New York's elevated railroads, where the loads were relatively light and speeds slow. Bringing long-distance and commuter trains into and out of midtown Manhattan, by comparison, represented a technological challenge of an entirely different magnitude. The new engines would be required to make two round-trips daily between Grand Central and Harmon, 34 miles to the north, each to be completed within one hour with a 550-ton train. Specifically, the engines had to be capable of adhering "to any regular schedule then in the timetable while hauling a maximum load of 14 Pullman cars and to make a smooth start followed by a uniform acceleration."[12] They would need to develop a minimum of 1,500 horsepower. The success of the entire Grand Central project hence depended on the design and production of entirely new technological systems.

Of course there would also have to be complete generating and distribution facilities, and so Bion J. Arnold, a prominent consulting engineer, was engaged to determine the power requirements. He undertook his studies using a dynamometer car cut into the consist of various kinds of passenger trains and then calculating the "reduction of the drawbar pull thus obtained to horse-power and eventually to kilowatts."[13] According to Arnold's determinations, the generating system would need to have a capability of supplying 1,800 kilowatts an hour, on average, and a yearly total of 15,768,000 kilowatt-hours for 250,285,710 ton-miles of service. His plan would eventually entail an electrified zone comprising the station and yard, the Park Avenue Tunnel, and the NYC's lines in the Bronx and Westchester County, 285 miles of track overall. The investment would be extraordinary. Wilgus first estimated the total cost of the entire project at $34,360.000.[14] In 1910, he put the final cost of the electrification alone at $43,600 per mile of single track.[15]

Technological Choices

The railroads were the leading innovators in the managerial revolution, as Chandler argues.[16] The "visible hand" in this monumental project outlined above involved not just the brilliant Wilgus but also a corporate structure that enabled such a project to be completed successfully. The NYC set up three separate offices that reported to Wilgus for the Grand Central project: Electrification, Construction, and Architecture. A 1906 *Railway Age* article emphasized the crucial role played by this formal structure:

> It is necessary to say that before entering on the work a thorough organization was evolved which has persisted and works with the accuracy of a machine . . . and takes cognizance of every question which may have an effect upon the other part of the work. Indeed, in this conception is found the secret of the regular progress which has been obtained, and of the certainty with which operations are conducted.[17]

In addition to the three special offices, Wilgus and the management of the NYC formed a Construction Commission and an Electric Traction Commission to oversee and coordinate the two most crucial aspects of the effort. The latter played the key role in introducing the new electrical technology. In addition to hiring Arnold, Wilgus engaged Frank Sprague to serve along with several company engineers, and the commission held its first meeting on December 16, 1903.

A number of complex issues faced the Electric Traction Commission. Alternating current or direct current? Third rail or overhead power distribution? How extensive the electrification? How many power plants, and where? What type of trains for commuter service? The commission marshaled the necessary information, considered each issue carefully, deliberated, and then made a recommendation. Perhaps the most important issue concerned AC versus DC. Each system had its vocal advocates, but Arnold recommended DC:

> While it is the writer's opinion that the alternating current railroad motor will yet prove to be the most efficient, all things considered, for long distance railroad work it has not yet in his opinion demonstrated its ability to start under load as effectively or accelerate a train as rapidly as the direct current motor. The line under immediate consideration was short, the trains numerous and rapid acceleration desirable, all of which made conditions favorable to the direct current motor.[18]

Wilgus supported Arnold's findings, citing "recent comparison tests of locomotives of the two types under exactly the same conditions which demonstrate that the one only designed . . . for direct current consumes from 15 to 25% less current than the one intended for both systems."[19]

The mention of engines designed for the use of "both systems" was a reference to the New Haven's decision to use AC for its Bronx–Stamford electrification, carried out at the same time as the Central's. Since the New Haven shared the NYC's 42nd Street passenger facilities—having negotiated a 400-year lease in 1843—this decision stunned the NYC's Electric Traction Commission. The so-called battle of the systems, AC versus DC, was a struggle among the major manufacturers of electrical equipment. But, as historian Andre Millard suggests, the issue was complex, and "winning the battle of words was a prerequisite to selling the larger systems."[20]

Behind the New Haven decision stood the figure of George Westinghouse and his firm, Westinghouse Electric. It was Westinghouse's chief rival, General Electric, that was awarded the contracts for the NYC's equipment. At that point, Westinghouse addressed an "open letter" to W. H. Newman, president of the Central, on the pages of the *Railroad Gazette*. He told Newman that the decision to go with GE equipment would cost an additional $15,350 per mile, and that the decision should be reconsidered. He also indicated that Sprague had a conflict of interest: Having sold his

patents and his own firm to GE, he said that Sprague stood to gain from the railroad accepting the DC system.[21]

Sprague immediately responded with his own "open letter" to Westinghouse in the *Gazette:*

> . . . with what poor grace comes your attack on me. . . . The true inwardness—and the littleness of your reference to me—lies in its suggestion that I am not independent enough to pass upon the merits of the proposal submitted to me, or that the New York Central Commission has not accorded your company fair treatment. So far as my friends are concerned I need no defense, for they know that my engineering instincts rise supreme above my personal interest when acting in an advisory capacity. . . . hence the attempt to get the New York Central Railroad to abandon matured plans, to terminate its contracts, and to adopt your proposal for a change of its equipment . . . is without the slightest basis of reason. . . . Your attack on me is misjudged and is unworthy of your own dignity. . . . I still recognize in you many elements of greatness. . . . My engineering convictions are my own. They are dictated by no man or corporation.[22]

Neither railroad was about to change its mind about the system it chose. Westinghouse had developed AC motors that could also utilize DC, so the New Haven would still be able to operate into the new Grand Central. AC proponents argued that DC was seriously limited by the loss of voltage in long-distance transmission, and yet the Central's decision was very carefully considered (as was that of the Pennsy to electrify its Manhattan Transfer–Penn Station service with DC). The electric engines that GE delivered to the NYC were a product of systematic research, careful design and construction, and a vigorous test program carried out in conjunction with the railroad. Nothing was left to chance. With so much riding on the introduction of electric service into Grand Central, everything had to work properly from the first moment.

Specifications for the locomotives were finalized in May 1903.[23] The Central's board of directors drove a hard bargain, at one point approving a letter from Wilgus to the GE management indicating that the prices of the initial proposal were "not entirely satisfactory." The railroad would pay no more than $30,526.31 for each of the thirty units and demanded that the first one be completed within eight months and then thoroughly tested "under the actual severe conditions recited in the specifications on an elemental stretch of track not less than five miles in length."[24]

The first tests took place in Schenectady on October 27, 1904; with eight cars in train, the prototype engine attained a speed of 55 mph. "Electric Locomotive Perfect, Test Proves," headlined the *New York Times*, quoting Wilgus as saying that it had "done even better than the builders thought possible and that questions of electric traction for high-speed trains [had been] solved for all times." More specifically, the new motive power would "relieve New York of all the trials and tribulation that travel through the tunnels has forced upon them for years past."[25]

In the months that followed, the new engine ran more than 45,000 miles of tests—112 eight-hour days of operation at over 50 mph. Condit describes the test program in superlative terms:

> The process by which the design concepts were translated into a practical working machine is perhaps the supreme example in technological history of technique carried to the level of a highly complex, multidimensional scientific enterprise. . . . In the technological revolution that produced electric mass transportation, the creation of the New York Central's pioneer class of electric locomotives constituted a decisive step.[26]

Conclusion

With Wilgus himself at the controls, the first electric train entered Grand Central on September 30, 1906. The *Times* reported that "No announcement could be better adapted to cheer the northward commuter in particular, and the traveling public in general. . . ."[27] Steam locomotives were replaced as fast as GE could deliver electrics, and by July 1, 1907—well over a year before the mandated deadline—100 percent of NYC service into Grand Central was powered by electricity. The new Grand Central itself was completed in February 1913, a little more than a year after Penn Station, with electric motive power being the key to both projects. Eventually, the yard at Grand Central was roofed over and a vibrant new neighborhood flourished in midtown Manhattan. Park Avenue north of 45th Street, once so disreputable, became the most fashionable business and residential address in New York.

The whole Grand Central plan succeeded so brilliantly because of concrete decisions made by individuals involved in the planning and execution of the enormous project—the "visible hand" of Wilgus, Arnold, Sprague, and the top managers of the New York Central. Grand Central represents the successful application of new technology to solve complex problems. Ninety years later, what was chosen so long ago still functions superbly. □

Notes

1 Quoted in Ron Westrum, *Technologies: The Shaping of People and Things and Society* (Belmont, Calif., 1991), p. 51.

2 Ibid., p. 76.

3 Merritt Roe Smith, "Technology, Industrialization, and the Idea of Progress in America," *Timeline* 8 (1991): 2.

4 David Marshall, *Grand Central* (New York, 1946).

5 William D. Middleton, *Grand Central: The World's Greatest Railway Terminal* (San Marino, Calif., 1977).

6 Deborah Nevins, ed., *Grand Central Terminal: A City within a City* (New York, 1982).

7 "Congestion of the Traffic at the Grand Central Station," *Scientific American* 83 (1 December 1900): 338.

8 William J. Wilgus, "The Grand Central Terminal in Perspective," *Transactions of the American Society of Civil Engineers*, Paper No. 2119 (October 1940): 997.

9 *New York Times*, 5 September 1900.

10 Carl W. Condit, *The Port of New York: A History of the Rail and Terminal System from the Grand Central Electrification to the Present* (Chicago, 1981), p. 54 .

11 Wilgus (n. 8 above), p. 1003.

12 Condit (n. 10 above), p. 12.

13 Bion Arnold, "A Comparative Study of Steam and Electric Power for Heavy Railroad Service," *Railroad Gazette*, 27 June 1902, p. 498.

14 William J. Wilgus to President Newman, New York Central Railroad, Box 1, William J. Wilgus Papers, Rare Books and Manuscripts Division, New York Public Library.

15 William J. Wilgus to Frank J. Sprague, 26 July 1910, Box 1, Wilgus Papers, New York Public Library.

16 Alfred Chandler, Jr., *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, 1977), p. 87.

17 "Electrification of the New York Central Terminal in and near New York City," *Railway Age*, 26 January 1906, p. 126.

18 Arnold (n. 13 above), p. 498.

19 William J. Wilgus, "The Electrification of the Suburban Zone of the New York Central and Hudson River Railroad in the Vicinity of New York City," *Transactions of the American Society of Civil Engineers*, Paper No. 1079 (1908): 76.

20 Andre Millard, "Thomas Edison, the Battle of the Systems and the Persistence of Direct Current," *Material History Review* 36 (Fall 1992): 26.

21 George Westinghouse letter to W. H. Newman, *Railroad Gazette*, 22 December 1905, p. 568.

22 Frank J. Sprague, "An Open Letter to Mr. Westinghouse," *Railroad Gazette*, 5 January 1906, p. 8.

23 "Minutes of the Electric Traction Commission," 19 May 1903, Box 6, Wilgus Papers, New York Public Library.

24 "Minutes of the Executive Committee," New York Central and Harlem River Railroad, 15 March 1899, Box 95, New York Central Railroad Papers, Rare Books and Manuscripts Division, New York Public Library.

25 "Electric Locomotive Perfect, Test Proves," *New York Times*, 13 November 1904.

26 Condit (n. 10 above), p. 11.

27 *New York Times*, 30 September 1906.