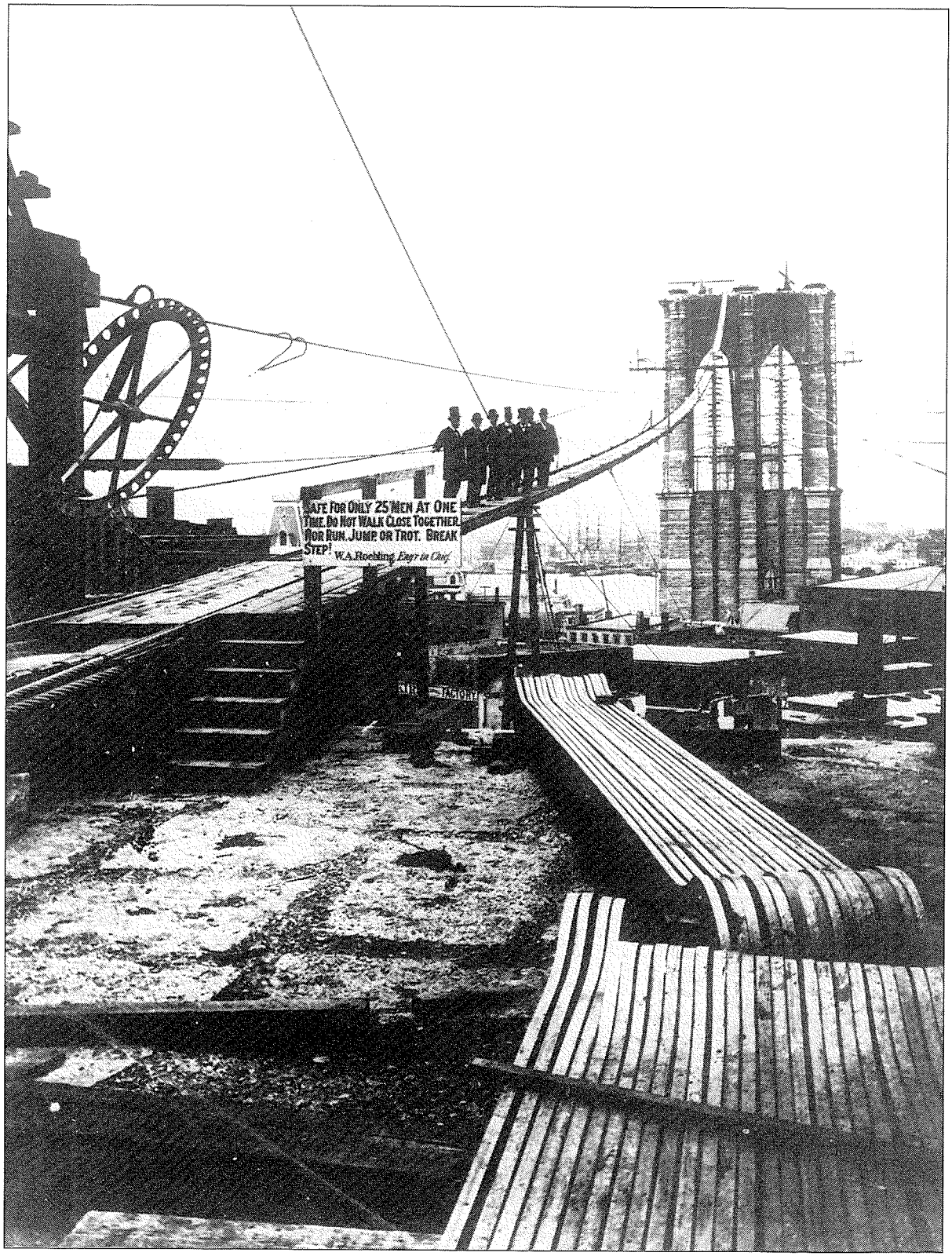


The Brooklyn Bridge was compared to the Acropolis and hailed as the crowning achievement of its age when it opened in 1883—acclaim of a sort that few 20th-century structures win.

The Saga Of American Infrastructure

President Bill Clinton's campaign pledge to "rebuild America" has lifted "infrastructure"—that most unlovely term for roads, sewage-treatment plants, and other essentials—near the top of the national agenda. Clinton's $80-billion shopping list includes not only the usual public works but "information superhighways," "bullet trains," and other exotica. In the past, the debate over how to build America has occasioned some of the great shifts in American political history, and, as Bruce Seely writes here, some very ingenious solutions. Assessing the nation's future needs, Jonathan Gifford suggests what some of those solutions may be.

A Republic Bound Together

by Bruce Seely

What a shock it has been to Americans to discover that steel and concrete are not forever, that the proud bridges built during the New Deal and the interstates laid out in the comfortable 1950s are as mortal as their makers and that the built environment is nearly as fragile as the natural one we have come to cherish.

As early as 1981, in a now-famous report entitled "America in Ruins: Beyond the Public Works Pork Barrel," writers Pat Choate and Susan Walter warned that "America's public facilities are wearing out faster than they are being replaced.... In hundreds of communities, deteriorated public facilities threaten the continuation of basic community services such as fire protection, public transportation, water supplies, secure prisons, and flood protection." But it took a series of surprises and disasters to drive home the point. In 1984, a bridge collapse on Interstate 95 in Connecticut killed several motorists and captured national headlines. In Pittsburgh around the same time, local authorities declared that it would cost $100 million just to begin repairs on 120 bridges that were too unsound to use or could only carry reduced loads. And less than a year ago, the nation witnessed the unlikely spectacle of a massive flood in downtown Chicago caused when construction workers accidentally punched a hole in a decaying tunnel built

in 1909. For days, much of Chicago's central business district was shut down. Today, the water-main breaks and sewage-plant breakdowns that once attracted only local notice seem to be symptoms of a disturbing national trend.

In the age of the microchip and genetic engineering, we have become accustomed to thinking of technology as something rarefied, almost immaterial, and certainly not something so thoroughly concrete as asphalt or steel or, for that matter, concrete itself. Infrastructure is technology. And more specifically it helps to think of infrastructure as *technological systems*, with each road, bridge, and drainpipe closely linked to an intricate—and as we have been reminded, delicate—network of supporting elements. And the more complex systems are often the most fragile.

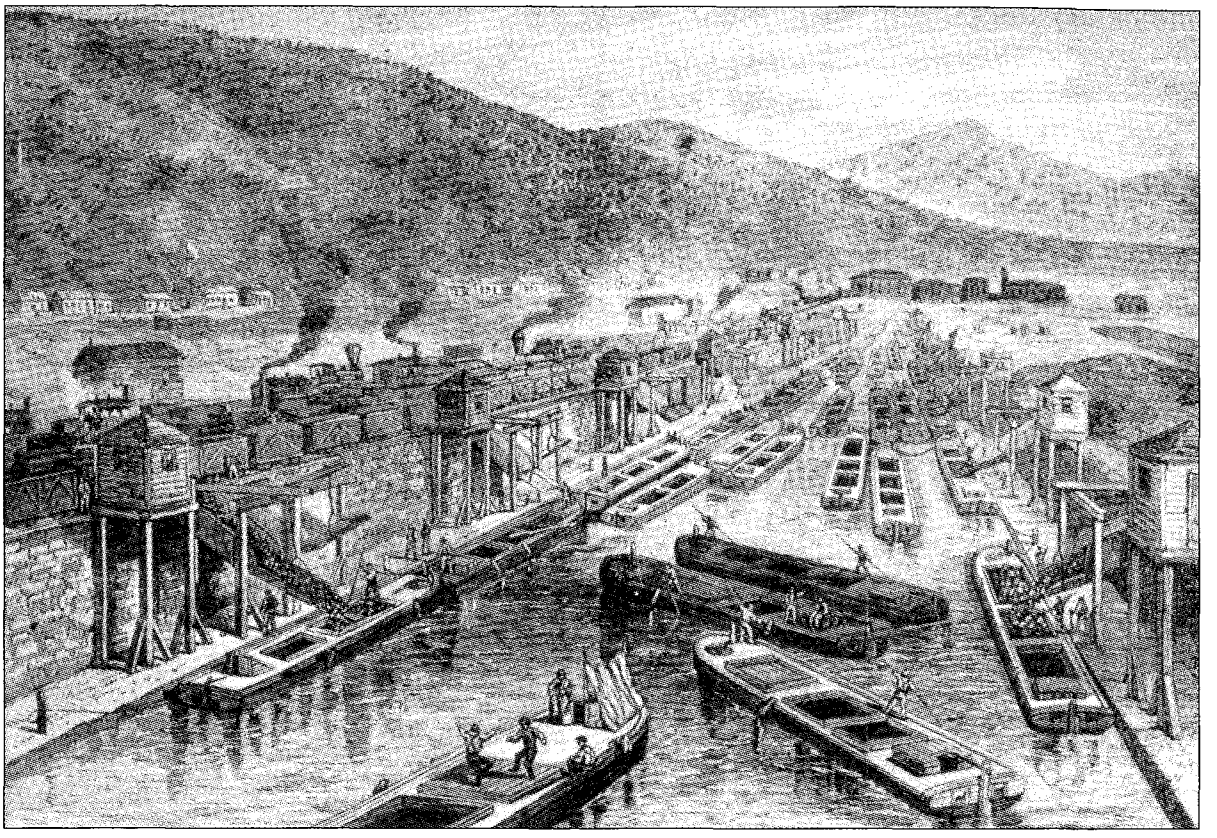
Originally, the term *infrastructure* referred to the permanent facilities required by the military—bases, airstrips, dry docks. Economists most likely extended the word to public works. What W. W. Rostow labeled "social overhead capital" in his famous book *Stages of Economic Growth* (1960) sounds today very much like infrastructure. Since the term gained recognition in the early 1980s, its meaning has steadily expanded. It is now applied to almost every support system in modern industrial society, public or private. Infrastructure is said to include not only roads and sewers, but national transportation grids, communication systems, media, housing, education, and, perhaps in the 1990s, computer networks and fiber-optic "information superhighways." For the purposes of this essay, however, I will concentrate on those things that provide crucial physical services: transportation, water and sewage, and power—the systems that historians Joel Tarr and Gabriel Dupuy call "technological sinews."

For almost two centuries, there has been broad public support in America for infrastructure development. The issue has been how, not whether, to build, and, more to the point, how to pay. Americans, rarely fettered by ideological dictates on the proper role of government, have shown great ingenuity in solving the latter problem. The political process, however, has never produced a coherent infrastructure policy. Our infrastructure has been cobbled together with little understanding of how one system affects and is affected by others—a failing that has at times brought disastrous consequences, including the decline of the railroads. For nearly a century, from the late 19th century to the 1970s, the nation dealt with the question of what to build and how to build it by vesting much control in engineers and other technical experts. Today our unquestioning faith in such expertise is gone, but infrastructure systems have increased in complexity, size, and expense. The 200-year ebb and flow of infrastructure debate, it appears, is approaching yet another high water mark.

Internal Improvements: The First Infrastructure Debate

It was infrastructure by another name that occasioned one of the great debates of the early Republic, and the outcome has continued to shape American attitudes. President George Washington and

Bruce Seely *is associate professor of history at Michigan Technological University and secretary of the Society for the History of Technology. His book* Building the American Highway System: Engineers As Policy Makers *(1987) won the Abel Wolman Award, given by the American Public Works Association and the Public Works Historical Society.*



Canals such as the Schuylkill, opened in 1822, were a boon to industry, but were soon made obsolete by railroads. Here, barges are loaded with coal in Port Carbon, Pennsylvania.

his treasury secretary, Alexander Hamilton, were early supporters of a federal role in what were called internal improvements, chiefly roads and canals, but it was left to their successors, Thomas Jefferson and his treasury secretary, Albert Gallatin, to take the first tentative steps. By 1800, many Americans recognized that links between the coast and the interior were essential for both economic and political reasons. "Good roads and canals," the Swiss-born Gallatin declared in 1808, "will shorten the distances, facilitate commercial and personal intercourse, and unite, by a still more intimate community of interests, the most remote quarters of the United States. No other single operation, within the power of the Government, can more effectually tend to strengthen and perpetuate that Union which secures external independence, domestic peace, and internal liberty."

The federal government struggled long and inconclusively with the issue of internal improvements. Gallatin's comment came against the backdrop of the rancorous debates surrounding the congressional decision to build the National Road from Cumberland, Maryland (on the Potomac River) to Wheeling, Virginia (now West Virginia) on the Ohio River. Opponents claimed that the federal government had no constitutional authority to construct the road. Supporters replied that the constitutional injunction to "promote the general welfare" was sufficient. Throughout its life, historian Phillip Jordan wrote in *The National Road* (1948), "the

project swung . . . on a swaying constitutional rope." But lofty constitutional scruples often seemed little more than a veneer over deep regional jealousies. Pennsylvania's representatives in Congress blocked construction for four years until a portion of the road was routed through the Keystone State. In 1820, Congress agreed to extend the road—then heavily used by farmers driving huge herds of cows and pigs to market—to the Mississippi River, but it only appropriated the necessary $4 million in 1825. Shortly thereafter, retreating from a direct national role in transportation, Congress decided to return the eastern sections to the states. (The road, long since paved, is now known as U.S. Route 40.) The westernmost sections in Indiana and Illinois were unfinished when Congress refused to provide more money in 1838.

Hesitation and ambivalence characterized most federal efforts to play a direct role in internal improvements programs. In 1808, Gallatin had presented his famous Report on Roads and Canals outlining a plan of extensive federal improvements. It included a coastal waterway and a turnpike from Maine to Georgia; connections between the four main rivers on the Atlantic seaboard and western rivers via water routes and heavy-duty turnpikes; roads to New Orleans, Detroit, and St. Louis; and connections between the Hudson River and the Great Lakes as well as a canal around Niagara Falls. Gallatin argued that only the federal government could marshal the necessary resources: $20 million over 10 years, or one-seventh of the government's annual revenues. But, growing tensions with England and the prospect of a costly war rendered the Gallatin plan moot, as even the treasury secretary agreed. A House committee noted that "the inauspicious situation" rendered the idea "inexpedient."

But Britain's success in blocking trade along the East Coast during the War of 1812 underlined the desirability of the kinds of internal improvements Gallatin had proposed. In 1817, Representative John Calhoun of South Carolina and Speaker of the House Henry Clay of Kentucky proposed their "American System" of higher tariffs to protect domestic manufacturers and underwrite a modest national transportation network. Noting hopefully that in the wake of the war "party and sectional feelings immerged [sic] in a liberal and enlightened regard to the general concerns of the nation," Calhoun declared, "Let us bind the Republic together with a perfect system of roads and canals." The plan occasioned more bitter wrangling, and when it finally passed Congress, President James Madison vetoed it as unconstitutional. Nor was his the only veto of internal-improvements legislation. President James Monroe vetoed another bill in 1822. President Andrew Jackson's veto in 1830 of the Maysville Turnpike Bill, which would have allowed the federal government to purchase stock in a 60-mile Kentucky turnpike, brought most discussion of a direct federal role in internal improvements to a close. Jackson later boasted in his farewell address that he had "finally overthrown . . . this plan of unconstitutional expenditure for the purpose of corrupt influence."

The Constitution was not the only obstacle to federal participation in internal improvements. Especially after 1820, sectional politics made any kind of consensus difficult. The most obvious example was the fierce struggle in the 1850s between North and South over the location of the eastern terminus of a transcontinental railroad, a conflict that prevented construction of the rail line before the Civil War. But the attitude was evident much earlier. Clay and Calhoun not withstanding, many southerners opposed any federal involvement in in-

ternal improvements, fearing that such programs would strengthen the central government and create a precedent for federal intervention in other state matters, meaning, of course, slavery. And there were those in the South who, satisfied with things as they were, simply saw no need for internal improvements.

The United States was virtually unique in its approach to—and difficulties with—internal improvements. France provided the model for most of Europe. In 19th-century France the state was the main actor, developing an elaborate bureaucratic structure that included schools to train engineers and agencies to plan and construct public works; French roads were probably the best in the world. In Germany and Russia, the state sponsored railroads and other transportation systems.

It was not, however, laissez-faire beliefs that constrained the federal government. Only England relied on private initiative to build its transportation system. In America, as historian Carter Goodrich shows in *Government Promotion of American Canals and Railroads, 1800–1890* (1960), the *state* governments actively supported road and canal construction, often through mixed public/private enterprises. Even many opponents of a direct federal role in internal improvements, including President Jackson, had no objection to state involvement. As Senator William H. Seward of New York explained, "a great and extensive country like this has need of roads and canals earlier than there is an accumulation of private capital within the state to construct them." Pennsylvania began the first comprehensive state road program in 1791, but a year later it also chartered the private Pennsylvania and Lancaster Turnpike Company. The company completed its 62-mile road in three years and began to earn a profit, sparking a turnpike boom in other states. New York chartered 67 turnpike companies by 1807; Connecticut authorized more than 50. By 1850, hundreds of

Internal improvements were a major issue in the election of 1828, but President Andrew Jackson's veto of a bill two years later spelled the end of a direct federal role in public works for decades to come.

turnpikes had been built, many with tax exemptions or other forms of state subsidy.

The pattern was repeated in canal development. New York's Governor DeWitt Clinton took the lead by beginning construction of the 365-mile Erie Canal in 1817. "Clinton's Ditch," as detractors called it, was such a success that a canal craze swept the states. Built by the state in eight years at a cost of $7 million, the canal paid for itself in less than nine years. It cut shipping time from Buffalo to New York City from 20 days to eight and opened vast new markets in the developing Midwest, stealing trade from New Orleans and helping New York leapfrog Boston and Philadelphia to become the nation's premier city in the span of a few decades.

Canals were soon being built everywhere, from New England to the Midwest. In Pennsylvania and Ohio, the state owned and built the systems, including Pennsylvania's hybrid "Main Line," which combined a railroad, two canals, and an inclined plane over the Allegheny Mountains to connect Philadelphia and Pittsburgh. Other states simply subsidized private ventures. By 1840, 3,200 miles of canal were open across the nation, representing an investment of $125 million—70 percent from government sources.

State governments played a more limited but still significant role in the development of railroads. The Baltimore & Ohio Railroad, chartered in 1827 and the first line in operation with 13 miles of track in 1830, started with a $500,000 investment by the state of Maryland. Local funds were even more important, as hometown boosters pinned their hopes for prosperity on the coming of the iron horse. The railroads quickly grew to 3,328 miles of track in 1840 and 8,879 miles in 1850. Initially, most rail lines did not connect with those of other companies, but by 1860 the 30,636 miles of track had begun to form a network.

Indeed, while federal construction of such improvements was out of the question after 1830, federal involvement in mixed public/private enterprises seemed far easier to accept. Even strict constructionists were willing to support such projects, as long as their states benefited. "Congress debated year after year . . . the subject of federal aid to internal improvements . . . . ," historian George Rogers Taylor observes. "But from the vantage point of the 20th century the prolonged constitutional debates seem forced and unreal . . . . Despite a parade of constitutional scruples, successive chief executives and congresses actually approved grants in aid in building specific roads, canals, and railroads." Washington gave land grants for roads in Ohio and Indiana in 1823 and 1827; four million acres were given for midwestern canals; and the government purchased $3 million in canal stock. In 1850 Congress gave 3.7 million acres of public land to the Illinois Central Railroad, and other land grants to 45 railroads in 10 states followed during the next seven years.

It was also during this period that the U.S. Army Corps of Engineers, founded in 1775, began to provide important technical services to public and private developers of infrastructure. The General Survey Act of 1824 authorized the corps to survey roads, canals, and later railroads—including, in 1853, transcontinental rail routes. The army engineers also played a critical role in river improvement after Congress provided $75,000 in 1824 for work on the Ohio and Mississippi rivers. By 1860, Congress had appropriated $6 million to remove snags and obstructions on western rivers and for harbor improvements. Eventually, the corps would go on to remake the Mississippi River valley with levees, dams, and channels. Its engineers would serve as an

important pool of expertise in other endeavors as well.

Government played a central role in internal improvements because it had to. Especially before 1850, private interests could not command enough capital to do all the work that needed to be done. Government officials made this investment believing that internal improvements brought economic prosperity. Then, as now, the state and local governments played the dominant role: Carter Goodrich estimated that they spent $425 million on internal improvements before the Civil War. No coherent plan guided their efforts—a lack that would be an enduring feature of American infrastructure efforts. Road and canal construction followed the rough outlines of the Gallatin plan, but no similar document guided railroad-building. Even discussion of a national plan was rendered virtually impossible by the intensity of the commercial and political rivalries. Company fought company; state fought state; region fought region.

Rapid technological change also made national planning difficult. The era of turnpike-building was quickly followed by a surge of canal construction, and before long the canals were threatened by railroads. Indeed, the wild success of the railroads emptied many canals of commercial traffic within a few years of their opening. Pity the poor official trying to choose among these competing modes of transportation.

The triumph of the privately run railroads seemed to show that governments were not good at picking winners. By 1850, Americans had lost much of their faith in public sponsorship. After the economic crises of 1837 and 1839, several states defaulted on canal bonds and a string of state constitutional amendments prohibiting direct state investment in internal improvements followed. When Ohio "privatized" its canal system in 1860, a newspaper editor wrote that "every one who observes must have learned that private enterprise will execute a work with profit, when a government would sink dollars by the thousands." This "homely maxim," historian Harry Scheiber noted, "would have been irrelevant in 1825, when only the state could command capital in sums sufficient to support canal construction."

In fact, the public continued to support certain types of infrastructure development. New York rebuilt the Erie Canal at a cost of $44 million during the 1840s. The railroads continued to receive generous federal and state assistance, even though it was accompanied by outrageous corruption. The first transcontinental rail line, whose completion was marked by the celebrated connection of the Union Pacific and Central Pacific at Promontory Point, Utah in 1869, was subsidized with 20-foot right-of-ways and generous federal land grants for each mile of track laid. All told, railroad companies received about 130 million acres of public land, an astonishing 9.5 percent of all the land in the country. By the time federal support for railroads slowed in 1872 amid scandal in the administration of President Ulysses S. Grant, the nation in its disorderly and often haphazard way had finally constructed the kind of national transportation network Albert Gallatin had envisioned in 1808.

Urban Infrastructure 1840–1920

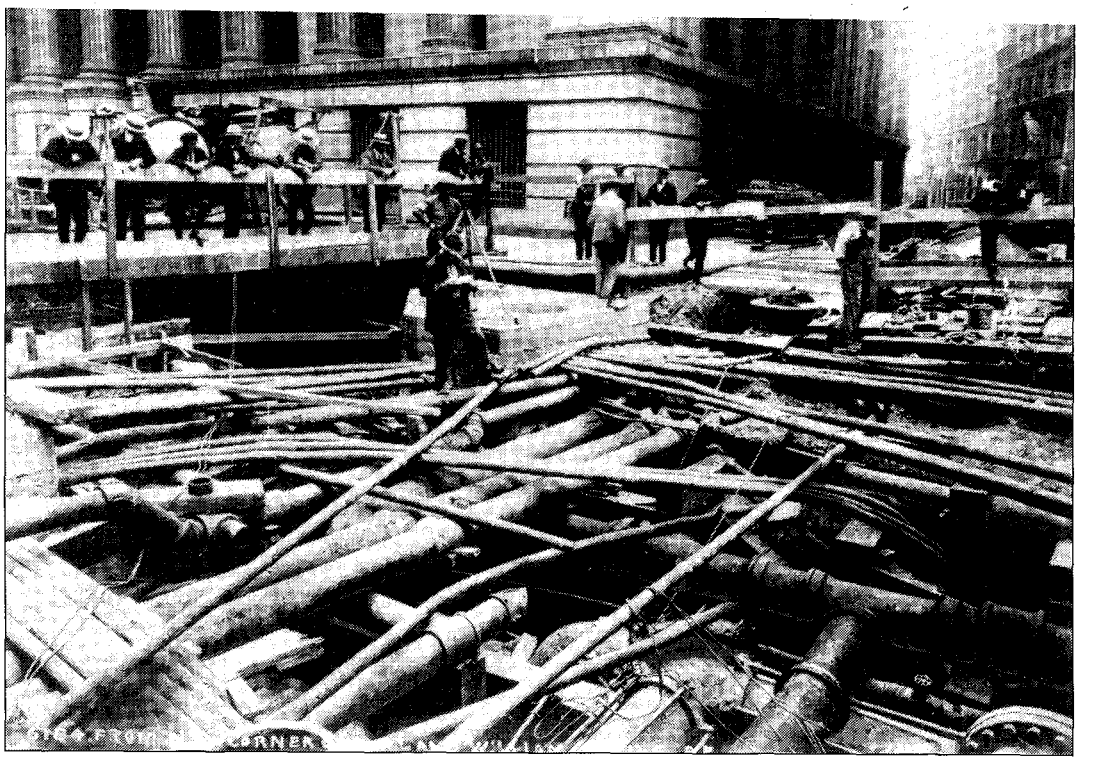
In America's cities, bulging with new immigrants and new industry, their foreign trade and commerce with the hinterlands nourished by the spread of roads, canals, and railroads, a different set of infrastructure challenges arose. Growing popu-

lation strained the ability of corner pumps to provide enough drinking water, while outbreaks of cholera and typhoid were frequent. Philadelphia's municipal government was the first to support improvements, after outbreaks of yellow fever took more than 4,000 lives in 1793 and another 3,500 in 1798. Between 1799 and 1801, two steam engines were built to pump water from the Schuylkill River to a reservoir for distribution through wooden mains. When the system opened, on January 27, 1801, *Poulson's American Daily Advertiser* hailed it as "a joyful circumstance to the citizens at large." The city's celebration was premature. The primitive steam engines consumed huge quantities of coal, replacement engines blew up in 1818 and again in 1821, and the log mains leaked. Not until 1822, when the Schuylkill River was dammed and water wheels replaced the steam engines, was the city adequately supplied with water.

Most other cities in this period let private companies build and operate water systems. But the quantity and quality of water was often limited, frustrating municipal efforts to clean streets and fight fires. The biggest cities soon followed Philadelphia's example of municipal ownership. Manhattan acted after a cholera epidemic in 1832 and a devastating fire in the business district three years later. In 1837, the city hired John B. Jervis—who received his engineering training on the Erie Canal—to design and construct a dam on the Croton River some 30 miles north of the city, a covered aqueduct to carry water to the city, a stone bridge across the East River, a 35-acre, 180-million-gallon reservoir in what was to become Central Park, and a 20-million-gallon distribution reservoir at Murray Hill. Jervis completed the project in 1842 at a cost of $13 million. This system, subsequently improved, was unusual by the standards of the day in that it represented an attempt to build for the future.

Beginning in the late 1850s, larger cities began to think in terms of networks such as the Croton system. Water-pumping systems grew more widespread, extensive, and complete, and other municipal systems emerged. Some of these were private, providing gas for heat and light, telegraphs, outdoor arc lights, and early electrical networks. Bridge-building and landfilling were undertaken in a few cities, as exemplified by the Brooklyn Bridge in New York (1869–83) and a land-reclamation effort that created the Back Bay area in Boston.

Historian Joel Tarr cites 1857 as the year marking the first efforts to move beyond fragmentary infrastructure development into more sophisticated systematic efforts. A case in point is the rise of the horsecar. Urban transportation at midcentury was dominated by the privately operated omnibus, a long, horse-drawn coach seating about 12 passengers. The cars were cramped, and service was expensive and slow. An alternative, introduced in New York City in 1832 but not elsewhere until much later, was the horsecar. Here the value of thinking in terms of systems was clear. By running larger cars on rails laid in the streets, it was possible for these street railway systems to carry twice as many people. But because they ran on fixed tracks they demanded coordination and planning. They also made economic sense only in larger cities, and a second horsecar system was not started until 1856, in Boston. A third opened in Philadelphia in 1858, and others in Pittsburgh, Cincinnati, and Baltimore in 1859. In short order, cities controlled the development of horse-drawn mass transit by granting franchises to private operators for specified routes. By the mid-1880s, 100,000 horses and mules were pulling 18,000 horsecars over 3,500 miles



Construction on Manhattan's Wall Street in 1917 revealed a tangle of pipes and conduits—an apt metaphor for cities' efforts to grapple with the infrastructure crisis of the day.

of track in American cities.

It was sewage, however, that really forced city officials to begin thinking comprehensively. Disposal of human waste was originally a private responsibility, and most city residences had privy vaults or cesspools. But the growing volume of sewage in the burgeoning cities contaminated groundwater and many street-corner pumps. Cities resorted to stopgaps: In 1844, Boston even forbade its residents to take baths without a doctor's order. Sewers, pioneered by European cities in the 1850s, were the only long-term solution. Brooklyn (1857) and Chicago (1858) were the first American cities to borrow the idea. The enormous cost and complexity of the systems left municipalities with no alternative: They would have to plan and build them themselves. And once again they were forced to plan systematically.

The largest cities were driven to such steps by 1870, while most smaller municipalities made the transition between 1890 and 1920. Water and sewer systems spread, and the first efforts at water filtration and sewage treatment began. Parks, beautification, and streets came under systematic control. After initial developments proceeded haphazardly, municipal officials monitored the many private activities, such as the wiring of cities for electricity, to ensure that systems were linked into networks to serve the general public. But as in the age of internal improvements, officials still failed to grapple with the interrelationships among systems. Every new solution showed an unnerving tendency to cause new and unexpected problems. The advent of running water exacerbated the health problems of inadequate sewage disposal, and the coming of horsecars created an enormous sanitation problem—each horse daily generated gallons of urine and about 20 pounds of what we euphemistically call solid waste.

As systems grew larger, it became more important to understand linkages. Not surprisingly, the first efforts at urban planning date from this era. By the last third of the century, Frederick Law Olmsted and Daniel Burnham, among others, were attempting to conceive whole cities, combining atten-

tion to parks, roads, water supply, and other services. Yet one cannot claim too much for planning before 1920. Most cities continued to tackle problems only when they could no longer be avoided. Most cities came up with solutions that had unanticipated consequences. To replace horsecars, for example, New York built steam-powered trains running on elevated tracks, only to find that the trestles blocked out the light, the trains showered cinders on pedestrians, and the noise was a constant annoyance to those below. Perhaps no one could have predicted the consequences of new technologies, but in the 19th century, few even thought about these issues. Most people simply embraced new technologies with enthusiasm.

Large, complex urban systems re-created the circumstances that led state government into the internal improvement arena in the 1820s—the need for capital. Within a single decade, the 1860s, municipal debt per capita more than doubled as cities scrambled to put infrastructure in place. With the economic depression of the early 1870s, many state governments imposed ceilings on municipal debt that sharply limited the ability of cities to pay for costly capital projects. But demand could not be restrained. In New York City, where congestion was terrible despite trolleys and elevated trains, subsurface trains seemed the only solution. Finding no private company with the resources to tackle the job, the city built 150 miles of subway lines between 1900 and 1940.

The one great exception to the private sector's limitations was the railroads, which embarked on an amazing round of track and terminal improvements at the turn of the century. The wealthiest lines in the country, in particular the Pennsylvania and the New York Central, completely reconstructed their main lines, built breathtaking new stations, and eliminated grade crossings. The Pennsylvania experimented with electric locomotives and completed a massive terminal improvement project in New York City that included tunnels under the Hudson and East rivers and a new Pennsylvania Station in Manhattan. No other entity, public or private, could afford to lavish so much money on infrastructure.

The cities' rapid growth and their flexible responses made the United States the leader in the development of urban infrastructure. A number of the technologies used in cities before 1880 had originated in Europe, including underground sewers, water-pumping systems, and paved streets. Thereafter, American systems were often bigger and more comprehensive and, sometimes, more innovative. It was the United States, for example, that pioneered electric power and electric streetcars.

The experience of Chicago, the fastest-growing city in the country in the mid-19th century, shows how rapid growth encouraged innovation. A water-supply problem bedeviled the city, despite the proximity of Lake Michigan and the Chicago River, because both had become quickly polluted. When the private water company failed to meet the challenge, the state legislature chartered a municipal water company in 1851. Its first step was to draw water from intakes far from shore, through tunnels and steam pumps built in the mid-1850s and expanded in the late '60s and '70s, and again in the '90s, when an intake crib was built four miles from shore. After 1861, engineer Ellis Chesbrough guided these efforts. Especially concerned with keeping sewage from getting into Lake Michigan, he proposed reversing the flow of the Chicago River in order to carry sewage down the Mississippi River basin. After some partial efforts proved inadequate, the city in 1892 began the 28-mile Ship and Sanitary Canal to re-

verse the Chicago River completely, excavating mountains of earth and rock. When the canal opened in 1900, typhoid deaths fell to 20, down from 2,000 in 1891.

Chicago was not alone in developing systems on such a breathtaking scale. By the 1880s, New York had found the Croton Aqueduct inadequate, and ultimately water was brought from the Catskills via another reservoir and a 92-mile aqueduct. During these same years, Los Angeles developed its Owens Valley project, the first in a series of public works that brought water to the arid city from the mountains many miles away. The political controversies and corruption these projects ignited are the stuff of legend. Somehow, each city's central business district and wealthy neighborhoods always seemed to get service first. High stakes and huge construction contracts bred corruption to match. Vast sums were squandered as Tammany Hall and other big-city political machines handed out construction contracts and franchises to political favorites. In Washington, D.C., during the 1870s, Boss Shepard's machine oversaw the construction of a $5-million sewer system that featured mains running uphill! The Owens Valley project in Los Angeles was rife with intrigue, some of which figures in the plot of Roman Polanski's film, *Chinatown* (1974).

In 1888, the British observer James Bryce labeled municipal government "the one conspicuous failure" of American society. Even as Bryce wrote, however, a reaction was setting in that would have profound consequences for American politics, helping to spawn the progressive movement and, fatefully, a longer-lived enthusiasm for the expert in public works.

Engineers had, of course, helped develop both internal improvements and early city infrastructure. But after 1870, technical experts began to play a much larger role in cities because they seemed to offer an alternative to corrupt politicians. Engineers argued that technical systems could be built and operated efficiently only if divorced from politics and put under the control of technical experts. The proof of the engineers' competence could be seen in the systems they designed and built. Each success strengthened their reputation as problem-solvers and soon they were hailed as managers as well as designers of technical systems. The engineers liked to think of themselves as something akin to family physicians. James Olmstead, a municipal engineer, wrote in 1894:

> He does know the character, constitution, particular needs and idiosyncrasies of the city, as the family physician knows the constitution of the family.... The city engineer... is responsible for holding the successive political officials to a consistent, progressive policy in all the branches of work under his charge. To him, even more than to the successive mayors, falls the duty of serving as the intelligence and brains of the municipal government in all physical matters.

As the municipal reform efforts of the 1880s and '90s blossomed into the national progressive movement, many Americans acquired what historian Robert Wiebe called a "childlike faith" in the efforts of engineers, viewing public-spirited experts, immune to graft and corruption and perfectly objective, as the answer to all types of problems. Wiebe added that it was widely assumed that university training, "immersing oneself in the scientific method, eradicated petty passions and narrow ambitions just as it removed faults in reasoning." This faith was evident, for example, in the rise of the "nonpolitical" city-manager form of local government, a system first installed in Galveston, Texas, after political leaders failed to cope with the aftermath of the hurricane that destroyed the city in 1900. The

preference for technical experts over politicians was reflected in such developments as the crusade for municipal ownership of utilities, strongly advocated by Mayor Tom Johnson in Cleveland, and the creation of "special districts" for sewage treatment, such as the Chicago Sanitary District (1889). It would take the better part of a century for Americans to learn the joltingly painful lesson that experts did, after all, have their own dangerous limitations.

The Reemergence of the Federal Government, 1920–70

Not even the most outspoken 19th-century supporter of federally sponsored internal improvements would have dreamed of a federal role in urban infrastructure. City problems were local by definition, requiring local solutions. Today, however, hardly a subway or sewage-treatment plant is built, indeed hardly a municipal bus rolls out of its garage, without Washington having been in some way involved. The change began in the early 20th century, thanks in large part to the broad public embrace of the progressive belief in apolitical expertise. This faith helped pave the way for increased federal regulation of the economy, beginning with the railroads, and the inauguration of a massive infrastructure program that to some extent competed with the railroads—the construction of highways.

Since the 1840s, responsibility for road-building had been left largely in the hands of local governments. But beginning in the 1890s, a "Good Roads" movement launched by bicyclists nudged the states into road construction, and by 1910 every eastern state had created a state highway department. In 1893, an office was formed in the U.S. Department of Agriculture to gather information about roads. The federal role remained strictly advisory, but that began to change after the agency was renamed the Office, later the Bureau, of Public Roads (BPR) in 1905, during the presidency of Theodore Roosevelt. This agency ultimately propelled the federal government into its leadership in highway affairs.

The bureau was a model progressive agency, headed during its first 13 years by Logan Page, a no-nonsense engineer determined to eliminate waste and corruption in road construction through efficient administration by engineers. Page's experts helped local and state officials develop better construction techniques and drafted model legislation for creating state highway agencies; they also helped build public support for good roads. Page, all the while insisting even to himself that he was nothing but a neutral technical expert, worked behind the scenes during Woodrow Wilson's presidency (1913–21) to orchestrate the Federal-Aid Road Act of 1916. This legislation modestly subsidized some state construction costs (the first continuing federal appropriation for roads) and, more consequentially, made state construction and maintenance subject to federal inspection.

The highway program was a significant departure. The federal government had not been the leading supporter of transportation of any kind since it began limiting active promotion of railroads in the 1870s. It was not money that made Washington the leader—the highway bill provided only $75 million over five years—but the recognized expertise of Page and other federal engineers. Newspaper magnate E. W. Scripps wrote to Page in 1909, "In all this great nation there are perhaps no other two men who have better opportunities to serve their country and who are making better use of them than are you and [conservationist Gifford] Pinchot. Despite the fact that neither of you have any

high sounding titles or official positions which in themselves would give you great distinction—perhaps just because of that fact, you are epochmakers." Page's successor, Thomas H. MacDonald, who headed the bureau from 1919 to 1953, gained such an extraordinary reputation as the sage of highway construction that car manufacturers, motorists, and other powerful interest groups took their lead from him in matters relating to roads, not the other way around. The basic policy that federal engineers advocated remained clear. They always sought to exclude partisan politics and the overt involvement of politicians from highway decisions. Funds were allocated to the states through a formula devised to prevent political tampering, and the states were required to create highway departments that met bureau guidelines. Moreover, federal engineers had to approve all locations, construction plans, specifications, and estimates. One of those guidelines, significantly, required that engineers run the state agencies.

By 1921 the highway policy MacDonald and his allies had developed was calling for a limited system of intercity roads, what would become the U.S. numbered-route system, the first national transportation system of any type in America. True, the railroads formed a nationwide network but without any overall plan directing the efforts of individual companies. For the first time since the Gallatin plan, federal officials were involved in designing systems.

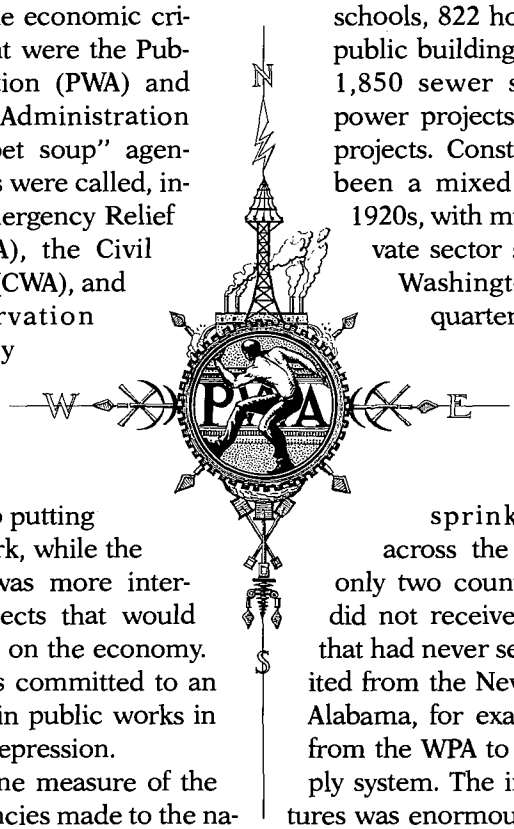
Roads were not the only technology whose development was assisted by the federal government during the 1920s. Commerce Secretary Herbert Hoover—who made his early reputation as an engineer and was popularly known as the Great Engineer—took a special interest in aviation, and in 1926 the Air Commerce Act authorized his department to designate and establish airports, operate and maintain air-navigation aids, and in other ways help stabilize the aviation industry through what became the Civil Aeronautics Board (forerunner of the Federal Aviation Agency). Federal subsidies for mail delivery, meanwhile, provided the foundation of commercial air service. Hoover's interests did not stop there. The Federal Radio Act of 1927, for example, allowed him to aid the nascent radio broadcasting industry. All of these efforts fit into the "associative ideal" advocated by Hoover as a means of developing cooperative business-government relations through trade associations.

Highways and Hoover's cooperative capitalism marked a shift in the federal role, but the Great Depression transformed infrastructure development in this country. As president from 1929 to 1933, Hoover, like Franklin Roosevelt after him, viewed big public-works projects as an important tool in combating massive unemployment. It was Hoover who launched the Reconstruction Finance Corporation and such ambitious federal projects as the Boulder (later Hoover) Dam on the Colorado River. But unable to rid himself of qualms over government "handouts," Hoover restricted the government to roads and "self-liquidating" projects that generated revenue. Roosevelt freely experimented with a wider array of programs, designed, as he explained, "to relieve the unemployment [and] to develop great regions of our country . . . for the benefit of future Americans."

Yet spending on public works did not increase as dramatically as one might think during the 1930s. Historian Roger Daniels notes that total public-works spending between 1933 and 1940 rose by 24 percent over the previous nine years. What changed momentously (but temporarily) was the federal share, which soared while local expenditures plummeted. State and local gov-

ernments spent $2.4 billion in 1930, but only $700 million in 1933. Federal spending, however, jumped from $250 million annually during the late 1920s to an average of $1.6 billion per year (1932–38), accounting for two-thirds of the total outlay.

Existing programs, especially highway construction, saw their budgets swell during the New Deal, but they were overshadowed by New Deal programs created specifically to tackle the economic crisis. The most important were the Public Works Administration (PWA) and the Works Progress Administration (WPA). Other "alphabet soup" agencies, as FDR's creations were called, included the Federal Emergency Relief Administration (FERA), the Civil Works Administration (CWA), and the Civilian Conservation Corps (CCC). Harry Hopkins, who headed the FERA and CWA before taking over the WPA, was most committed to putting the unemployed to work, while the PWA's Harold Ickes was more interested in building projects that would have a long-term effect on the economy. But both were activists committed to an increased federal role in public works in order to combat the Depression.



Statistics provide one measure of the contribution these agencies made to the nation's infrastructure. Roads were among the most important projects; between 35 and 45 percent of all workers on federal relief worked on highway projects of various types. The CWA, in its brief existence during 1933–34, repaired 255,000 miles of roads. Through 1938, the PWA provided more than $1 billion for more than 11,000 individual highway projects. The WPA spent $3.69 billion on roads during its existence (1935–43), building 572,000 miles of roads, 67,000 miles of city streets, and 78,000 bridges. But much more important, 20 percent of PWA funds and at least a third of WPA funds went for wages; that is, directly into the pockets of the unemployed.

Driven by the need to put people to work, the federal government now found itself engaged in fields where it had never before been involved. A listing of PWA projects includes many buildings (7,488 schools, 822 hospitals, and 4,287 other public buildings); 2,582 water systems; 1,850 sewer systems; 375 electric-power projects, and 470 flood-control projects. Construction of airports had been a mixed enterprise during the 1920s, with municipalities and the private sector splitting costs. By 1938, Washington was footing three-quarters of the bill.

New Deal public works reached into every nook and cranny of the country. The PWA alone sprinkled 35,000 projects across the landscape; there were only two counties in the country that did not receive a PWA project. Towns that had never seen a federal dollar profited from the New Deal largesse. Wilton, Alabama, for example, received $30,909 from the WPA to build its first water-supply system. The impact of these expenditures was enormous.

The public's imagination, however, was captured by the large projects underwritten by the PWA. These ranged from the Tennessee Valley Authority to the huge Grand Coulee and Bonneville dams on the Columbia River in the Pacific Northwest, to Fort Peck Dam on the Missouri. In the cities, there were New York's LaGuardia Airport (built largely with WPA funds), Chicago's massive water filtration plant (PWA); flood control in the Los Angeles area; and the Pennsylva-

nia Turnpike. In New York City, federal funds helped build parks, highways, the Lincoln Tunnel, and several bridges (including the Triborough Bridge).

The master builder of the era was undoubtedly New York's Robert Moses, "the power broker," as he was styled in Robert Caro's scathing 1974 biography. During the 1920s Moses had pioneered the development of a dozen state-chartered authorities—at first state park authorities, and later the Triborough Bridge, Henry Hudson Bridge, and Marine Parkway authorities. Moses capitalized on the progressive faith in expertise, managing to insulate his authorities from politics in the name of the efficient pursuit of technical goals. According to Caro, Moses was a ruthless "emperor" who went so far as to keep dossiers of embarrassing information on his political enemies, but he had the public image of a public servant who could get things done even if toes got stepped on in the process. In retrospect, he might be seen as the J. Edgar Hoover of public works.

Vastly extending the reach of his authorities through the mechanism of bond financing supported by toll revenues, Moses monopolized public-works projects in the metropolitan region, thrilling the public with his ability to ram through roads, bridges, and parks against all opposition. Moses was fully prepared when FDR began pouring money into such projects. Although the power broker and the former New York governor loathed each other, Moses snared a big share of New Deal money because his engineers at the Triborough Bridge Authority and other outposts had plans and drawings ready when the New Deal agencies had money to spend. Between 1933 and '36, Moses garnered one-seventh of all WPA funds; by 1938, New York had collected $1.15 billion in federal relief funds.* With that money, Moses transformed the face of New York City. "In the 20th century," wrote the rueful critic of megalopolis, Lewis Mumford, "the influence of Robert Moses on the cities of America was greater than that of any other person."

During World War II, government officials continued to plan big public-works programs, fearing the return of depression in peacetime. Infrastructure and employment programs had become firmly linked. The 1944 Federal-Aid Highway Act provided a huge increase in federal aid, $1.5 billion over three years, for an expanded system of primary, urban, and secondary roads. The bill also authorized but did not fund a new network of interstate roads between cities. As it turned out, however, inflation was the major worry after the war, and President Harry S. Truman sought to restrain federal spending. Yet the growing number of cars on the roads made it seem obvious to all that a massive new highway system was essential. Feeling financially pinched, many states resorted to the old mechanism of toll financing, much to the disgust of MacDonald and his engineers at the Bureau of Public Roads, who regarded tolls as a double tax on motorists (who already paid fuel taxes to underwrite roads). But the Pennsylvania Turnpike, built with New Deal aid in 1939–40, had shown that the public would pay for the use of high-speed limited-access highways. Now several states followed Pennsylvania's example. By October 1953, 762 miles of toll road were open with 1,077 more miles under construction; by 1963 the total stood at 3,557 miles. Once again, the builders of infrastructure showed that

*Government officials have learned a lesson from Moses—be prepared! A recent survey by the U.S. Conference of Mayors of 506 cities found 7,252 public works projects "ready to go" but lacking funding. At a cost of $26.7 billion, these projects would provide jobs for 418,000 people.

INFRASTRUCTURE TO WHAT END?

Neoclassical economists so dominate the discussion of industrial policy these days that we often forget that what we are discussing is the shape of the material world, not simply how we will pay for its construction. Whether we charge or pay cash, we will have to live in the world that we build. We profess to worry about the burdens that the federal debt and our pollution of the natural environment will impose upon our children, yet we show precious little concern for the quality of the material culture—the built systems—in which they will have to live.

Shaping the material world through architecture and the construction of what we now call infrastructure is a timeless expression of human character. Karl Wittfogel, the scholar who originated the "hydraulic society" thesis, showed how massive irrigation projects provided the material basis of early societies. Lewis Mumford reminded us that the early Egyptians performed great feats of human organization to create the mammoth construction projects that built the pyramids. Later civilizations, including modern ones, became accustomed to creating what Mumford labeled "megamachines," orchestrating a variety of human and economic resources in the pursuit of certain goals.

Yet system building in the modern era has taken on a new cast. We can assume that the pyramid builders used mostly available "off the shelf" technology. This was true, too, of the creators of canals and railroads in the 19th century. Since World War II, however, large-scale construction efforts have taken on the character of research-and-development projects. Scientists were so central to the creation of the wartime Manhattan Project that many commentators have mistakenly seen it as a scientific program rather than as what it was: a science-based construction project designed to create a system for manufacturing explosives.

After the war, the Manhattan and Radiation Laboratory projects in the United States and the Peenemünde rocket project in Germany became paradigms, or exemplars, for science-based, military-funded development of weapons systems. In the United States, these efforts achieved an enormous scale. Measured by the investment of human and material resources in a brief period of time, they were the most massive construction projects in history; they were high tech and science-based; and they included new managerial techniques and forms.

The civilian infrastructure efforts of the future will need to draw upon these new forms of management but use them to pursue different values. New techniques such as operations research and systems engineering require the creation of interdisciplinary committees of scientists, engineers, academics, and government experts to identify problems and the strategies for solving them. New organizational forms—interdisciplinary teams of engineers and sci-

they could respond creatively to financial limitations.

Sentiment for a more ambitious program kept building. In 1954, President Dwight D. Eisenhower, influenced by public demands for more roads and by the emergence of a congressional consensus about such a program in the 1954 federal highway bill, called for a "grand plan for a properly articulated highway system." Two years later, the legislation authorizing the 42,500-mile National System of Defense and Interstate Highways arrived on his desk. In fact, the bill owed almost nothing to defense concerns and passed Congress only because it also provided more money for every other federal-aid road system, rural, urban, and primary. Not quite pork-barrel, the bill still provided something for all elements of the highway community. For the interstate network alone, it authorized outlays of $25 billion over 12 years, to be provided by highway-user taxes (gasoline taxes and excise taxes on tires) deposited in a highway trust fund. The work was to be carried out by the states. The funding base (Washington picked up 90 percent of the tab) and the allocation of funds by formula for construction of a predefined system were reflections of the continuing belief that roads should be kept out of the reach of politicians.

The trend toward more federal involvement showed up in other areas as well. The new Atomic Energy Commission, for example, encouraged the nation's electric utilities to become involved in efforts to develop civilian nuclear power reactors. By

entists aided by skilled craftspersons—are also needed to preside over the design and development of the systems. These techniques and forms have already been transferred to the civilian sector, where, for example, system builders (which can mean individuals, groups, or institutions) now design and construct large health-care systems that incorporate hospitals, health-insurance agencies, and pools of medical practitioners. Large engineering and construction firms use operations research and systems engineering techniques, as well as collective research and development, when they preside over massive regional energy developments.

The military programs of the past were shaped by military, political, and economic values, and their products reflected a preoccupation with control and power. Environmental impact, for instance, did not rank high on the scale of design priorities during the Cold War. Nor did the designers and developers of the military systems incorporate aesthetic values into their designs. We now have the opportunity to embed different values into our infrastructure. The next generation's systems should articulate aesthetic and socially benign values, as well as economic ones. But we also face the melancholy prospect that the national-defense emphasis of the past will be replaced only by a fixation on raw economic values. If so, our built environment will express cost effectiveness; it will not project a concern for community, individual fulfillment, or beauty.

In part because of the return of free-enterprise ideology, the federal government has in recent decades only hesitantly involved itself in the construction of the civilian built world. But other industrial nations, including France, Germany, Sweden, and Japan, have established industrial and technological policies that involve substantial government influence without bringing on the ill effects that free-enterprise ideologues have predicted. Government involvement abroad is usually justified on the basis of promoting rational economic development, but policy makers and the public also have called for government funding, regulation, and management in order to create systems expressing values other than economic rationality. A case in point is the German government's approach to the rehabilitation of eastern Germany, where in order to fulfill the ideal of a united Germany the government is investing heavily in telecommunications and electric power. Americans should now ask how well their government's new industrial policy will express the values of the people and how effective our values will prove in shaping the construction of a physical environment that will nurture, not only materially but spiritually, our own generation and those to come.

—*Thomas P. Hughes*

Thomas P. Hughes *is Mellon Professor of the History and Sociology of Science at the University of Pennsylvania. His most recent book is* American Genesis: A Century of Technological Enthusiasm 1870–1970 *(1989).*

1960, the first generation of commercial reactors was in operation, including the Dresden plant southwest of Chicago and the Yankee plant in Massachusetts. Washington anted up $1.3 billion for the program, the utilities $500 million.

The golden age of infrastructure development in the United States came during the 1960s and '70s. During the 1950s, unemployment relief ceased to be the only justification for federal infrastructure spending. Now the New Frontier and the Great Society brought a surge of activism and with it new federal agencies such as the Department of Transportation (1968) and the Environmental Protection Agency (1969) that were given major responsibilities in infrastructure. Major legislation such as the Solid Waste Disposal Act of 1965 and the Urban Mass Transportation Act of 1970 ($3.1 billion over five years) drew Washington into areas it had paid little or no attention to before. The 1972 Water Pollution Control Act greatly expanded what had already become a large program in the 1950s by providing massive funding for treatment plants—$5 billion for 1973 and $6 billion for 1974. The question of how to pay had found a new answer—Uncle Sam. The answer ushered in a new era.

As always, pork-barrel politics helped make these programs popular. Yet it is difficult to recall today the high optimism that propelled them: the belief that all problems, from poverty to

traffic jams to pollution, could be solved. Nothing was more important to this new spirit than the continuing progressive-era faith in "nonpolitical" experts, epitomized by the new National Aeronautics and Space Administration. As historian Walter McDougall writes in his study of the space program, *The Heavens and the Earth* (1986): "To [President Lyndon B.] Johnson, the space program was a model of the role government should play in society, and the role technology should play in government.... Whether in decaying cities, or Third World jungles, American technology would overwhelm the enemies of dignity."

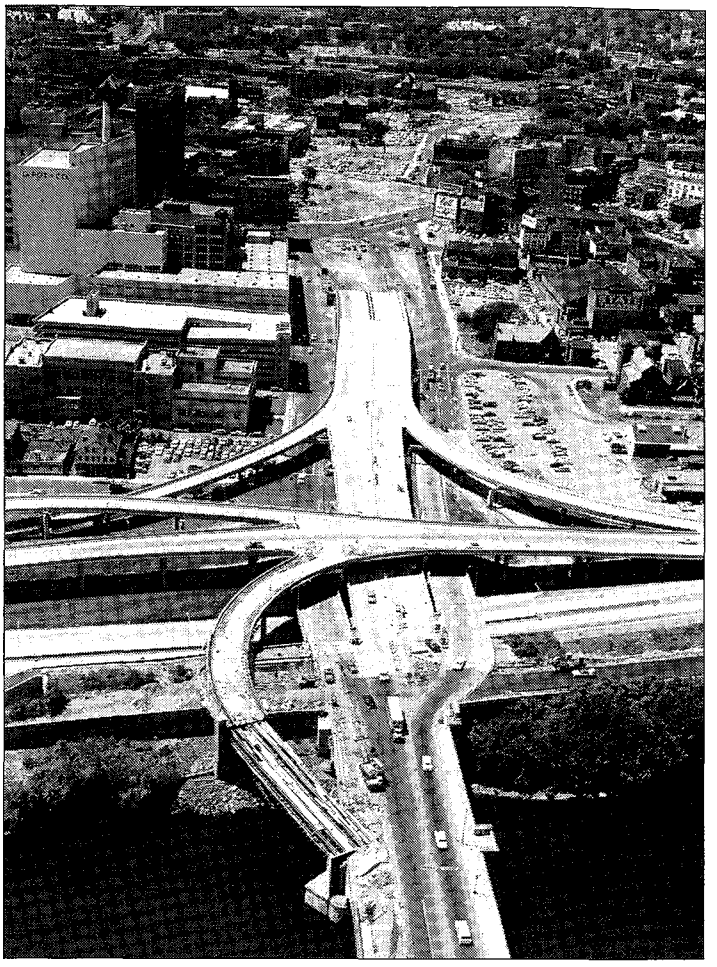
Yet even with all the prestige accorded the experts, the nation after World War II seemed to be no more able to coordinate infrastructure projects than before. Even experts such as Thomas MacDonald made little effort to establish detailed priorities, preferring instead to use formulas to distribute funds for designated networks in such a way as to minimize discord among both politicians and members of the road-building fraternity. But this approach did not guarantee that the most important routes got built first.

Similarly, intermittent efforts to create a centralized federal department of public works came to nothing. During the New Deal, Roosevelt could have gathered all public-works efforts under one roof, but instead he chose to create many agencies and seems deliberately to have encouraged competition between the PWA and WPA. Other agencies had even longer histories of rivalry, most notably the Bureau of Reclamation and the Corps of Engineers, which vied for supremacy as dam-builders. Worse than the waste that resulted from this kind of competition, however, was the way federal programs often worked (and still work) at cross purposes.

Part of the problem is inherent in the nature of public works as they have evolved during the 20th century, dominated as they have been by federal patronage. Highways and dams are built not only to provide transportation and irrigation but to create jobs in bad economic times, to return political favors, and to serve a variety of other purposes. It is difficult to build "technically correct" projects when that is not the sole aim of public works. Federal planning has expanded enormously since the New Deal—when it was sometimes possible to get federal grants without so much as a blueprint as long as an engineer was on the site—but the problem remains. Today, every aspect of the federal highway program requires careful planning: estimates of future traffic demands, environmental impact, costs of construction, and so on. But this kind of planning does not take account of overarching transportation needs. Highway planners look only at roads, airport planners only at airline traffic.

The near demise of the nation's railroads is the classic case of narrow planning gone awry. After the turn of the century, Washington subjected the railroad companies to increasingly onerous and sometimes ill-advised regulation, preventing them, for example, from abandoning unprofitable rail lines without approval and from operating their own bus lines. It also began pouring money into the road system and aiding civil aviation with barely a thought to the consequences for railroads. Nor was the federal government alone in its shortsightedness. Beginning in the 1920s, most state and local governments made costly efforts to accommodate the automobile even as they piled new restrictions on existing street rail companies. The automobile, according to historian Paul Barrett, was accepted as a panacea for urban problems, while the debt-ridden streetcar companies, long a source of municipal corruption, were seen simply as problems. Now we are paying the cost for these un-

wise decisions. In 1956 only seven cities operated transit systems; by 1975, a total of 91 percent of the nation's transit riders rode municipally owned systems, virtually all of them chronically debt-ridden. Ironically, cities are now using federal mass-transit aid to build light-rail commuter systems—a fancy name for the streetcar systems destroyed during the past half-century. The federal government itself, meanwhile, was forced to step into the interstate passenger and freight railroad business during the 1970s.



Thrusting through Hartford, Connecticut in July 1961, Interstate 84 was a symbol of "progress." Within a few years, however, the Freeway Revolt brought work on many urban expressways to a halt.

These failures no doubt contributed to the sea change that transformed infrastructure development beginning in the 1960s and helped bring the brief golden age to a close: Americans lost faith in experts. Until the 1960s, for example, road-building was one of the most popular government programs ever. More roads meant more jobs, more business, more convenience, an easier drive to work. But when the interstate program began to push multilane highways through city neighborhoods, uprooting thousands of individuals and destroying entire communities, support began to crumble. As early as 1963, even the mighty Robert Moses began to appear in a lesser light, and his admirers on the editorial board of the *New York Times* confessed that "we must admit to a growing disenchantment with great urban highway and expressway schemes." Within a few years, endless controversies finally revealed to the public "all his egotism, arrogance, and ruthlessness," Robert Caro wrote. "His name had become a symbol for things the public hated." In 1968 the man who had transformed his city and much of his state, who had once held 14 public positions at the same time, was forced into ignominious retirement. The high-handedness of highway agencies everywhere spawned resentment and opposition, and critics found support in the emerging environmental movement. The "Freeway Revolt" was

marked by a string of polemical books, such as Helen Leavitt's *Superhighway—Superhoax* (1970), a slashing account of American roadbuilding that hammered at the almost complete exclusion of the public from the planning process. In San Francisco, New Orleans, Boston, Philadelphia, San Antonio, and other cities, the freeway rebels took their case to court, slowing and finally stopping much urban expressway construction.

As the environmental movement gained strength, almost all large engineering projects ran into public resistance. The critics got a helping hand from the National Environmental Policy Act of 1969, which mandated environmental-impact statements and public hearings for all federally funded projects. Costs soared as construction timetables lengthened into the indefinite future. Many blueprints were simply filed away. Nuclear power, stopped nearly dead in its tracks even before the accident at Three Mile Island in 1979, is only the most extreme example. Even projects intended to clean up the environment proved difficult to build, encountering resistance of a sort so widespread that it has acquired its own acronym—NIMBY, for Not In My Back Yard. In New York City local activists halted plans for a huge sewage-treatment plant near West Harlem designed to serve more than a million people. Residents opposed the 30-acre plant because it blocked access to the Hudson River; others saw racism lurking behind the site selection. The plant, greatly altered by long negotiations—it even includes a park and playground on the roof—did not open until the early 1980s, two decades after it was proposed.

The assumption that politics and technology should not mix had been a touchstone of American infrastructure efforts since the progressive era. Engineers and politicians had deliberately insulated decisions about infrastructure from political control. By the late 1960s, that seemed to be the basic problem. Experts had come to view public hearings as stages where they would unveil their magnificent plans to an eager public, not as forums for the discussion of alternatives. As opposition appeared, engineers tried to keep projects moving through the pipeline using the same language of efficiency that had always worked before. They rejected criticism as irrational and condemned environmental concerns as simply outlandish. Above all, they blamed the media for their problems.

This arrogance communicated itself to the public, and it ultimately caused the engineers' downfall. In state after state, political control was reestablished over highway agencies. Engineers were replaced as the top operating officials by accountants, or even worse, by lawyers. In Massachusetts, the first person appointed to head the new Massachusetts Department of Transportation in the early 1970s was a prominent critic of freeway construction in Boston. Engineers continued to implement policy, but governors and legislators now set the boundaries within which they operated. The progressive faith in apolitical experts as the best servants of the public was gone.

If the golden age of infrastructure had any chance of surviving this loss, that chance perished with the economic crisis of the 1970s. Rising inflation, compounded by the energy price jumps after the Arab oil embargo of 1973–74, cut sharply into government's purchasing power. Rising interest rates discouraged state and local borrowing. And as consumers cut energy consumption, revenues from gasoline taxes dropped. Statistics on infrastructure are often contradictory, but on one thing they agree: The mid-1970s mark a postwar turning point. The growth of federal infrastruc-

ture spending stopped.

The Reagan administration's budget ax and its deficits knocked public works back yet another step. By 1988 even the normally combative Congressional Budget Office seemed resigned, concluding that the nation's infrastructure was largely built and urging that the federal government focus on maintenance rather than additional construction. The United States now invests less in infrastructure, measured as a percentage of gross domestic product, than any other industrialized country.

All of these developments—financial constraints, waning public support, the loss of faith in experts, and the return of politics—have transformed the way America builds infrastructure. With fewer federal subsidies available, state and local officials have shown a renewed willingness to experiment. "Privatization" became the new mantra during the 1980s, yielding a variety of highly publicized efforts, both in America and abroad. In Europe, the century-old dream of linking Great Britain to the Continent is being realized by a private "Chunnel" consortium, and nationally owned railroads in Germany and elsewhere may well go on the auction block. The California Department of Transportation has proposed a series of privately funded toll-road and bridge schemes as a way of building needed arteries. The $2.5-billion high-speed rail link now being planned between Orlando and Tampa is a private venture, as is a proposed 14-mile toll road from Leesburg, Virginia, to Dulles Airport in the congested outer suburbs of Washington, D.C.

Yet for all the apparent upheaval of the past 15 years, many apparent reforms and calls for new thinking are less revolutionary than they seem. We have in large part only reinvented the wheel. The "privatization" efforts of the 1980s, virtually all of them receiving some kind of public subsidy or support, represent a return to what Carter Goodrich called "mixed enterprises" in infrastructure. They may serve the nation well. Yet we have been rediscovering old problems as well as old answers. Today, public officials and others who concern themselves with infrastructure are demanding the elimination of the pork-barrel decision making process. They believe that a more centralized effort is needed in order to establish priorities and to ensure that technical, not political, criteria govern the distribution of funds. Pat Choate and Susan Walter, for example, call for a national capital budget to permit a comprehensive examination of public-works spending.

No doubt we need a broader vision than we have had in what has passed for infrastructure planning in the past. Roads and other infrastructure powerfully influence the patterns of physical and spatial development on the national landscape, literally setting choices in concrete and restricting the options of later generations. Choices should be made carefully. Calls for national planning and more centralized control of infrastructure seek in some ways to return to the traditional progressive approach—the elimination of inefficiency, waste, and pork-barrel thinking, in short, the bypassing of politics. But any such effort would require finding a way to restore some of the public's lost faith in experts, who would, after all, have to do the planning and the coordinating. And if there is one lesson to be drawn from an historical perspective on American infrastructure development, it is that politics can be denied in the short run, even papered over, but never escaped.

TOWARD THE 21ST CENTURY

by Jonathan Gifford

Years before President Bill Clinton came to Washington with his campaign pledge to spend an additional $20 billion annually on America's infrastructure "to develop the world's best communication, transportation, and environmental systems," economists and others were talking about the need to spend more on public works. Their debate has been almost entirely about one question: How much more? Usually overlooked in these discussions is the real infrastructure dilemma of the 21st century—not how much to spend but how to decide what to build and where to build it.

For several reasons, our old ways of deciding these matters simply do not work anymore. Americans today are far more skeptical about the value of new roads, bridges, and sewage-treatment plants—especially when they are located in their own backyard. Their faith that decisions about public works can be safely left in the hands of public officials, engineers, and other technical experts is gone. Reflecting in 1985 upon the final demise of Westway, the proposed interstate along Manhattan's West Side that had been held up for 30 years, Senator Daniel Patrick Moynihan (D.-N.Y.) wrote, "There is a kind of stasis that is beginning to settle into our public life. We cannot reach decisions. Central Park could not conceivably be built today as it was when there was enough power in Tammany Hall to make the decision.... We don't have that capacity."

The persistence of the public-works pork barrel has also contributed to public skepticism. In the same year that Moynihan decried the death of Westway, his Senate colleague, John Stennis (D.-Miss.), celebrated the opening of the $1.8 billion Tennessee-Tomigbee Waterway, recently described by the *Atlanta Journal Constitution* as "a 234-mile broken promise." A classic pork-barrel project, the waterway carries only one-tenth the commercial barge traffic that had been projected.

In an important sense, however, the loss of faith and direction in the way we have built infrastructure in the past is for the better. The methods of the master planner and master builder, the techniques of New York's Robert Moses and his New Deal counterparts, are poorly suited to a dynamic economy whose demand for new infrastructure is unpredictable and constantly changing. In the new economy, the neat but rigid prescriptions of technical experts and planners are as likely to yield expensive and underused projects as improvements in national productivity. There are solutions. Privatization and user fees, touted by many analysts chiefly as ways to raise capital for infrastructure and to streamline operations, have much broader implications than have yet been appreciated. They offer the best guide to creating

infrastructure that can meet the nation's rapidly changing social, economic, and environmental demands.

A growing awareness of the human and environmental costs of roads, dams, and other infrastructure projects brought the public's faith in experts to an end during the 1960s and '70s. Increasingly, Americans came to believe that efficiency, the totem of the experts, is *not* the sole value. People and communities matter; the environment matters. In fact, under close scrutiny the technically objective criteria that engineers and other experts employed turned out to have some rather arbitrary foundations. In some cases they amounted to little more than engineering aesthetics. Why did a new highway have to cut directly through a certain poor neighborhood? Perhaps only because some engineer wanted an extra five miles per hour of speed on a curve. Judging whether that extra margin of speed justified displacing dozens or perhaps hundreds of poor families is not a purely technical question. It is a question of values—and of money and political power.

Because of these concerns, decisions have been opened up to the public, notably with a 1969 federal law requiring an environmental-impact statement and extensive public hearings for any project receiving federal support. This reform and others like it have stopped the worst abuses. It would be unthinkable today to embark on a major infrastructure project without careful consideration of its social, economic, and environmental costs.

An excellent example of how the reformed process works is the Glenwood Canyon project on Interstate 70 west of Denver, one of the only major highway routes west from Denver over the Rockies. The canyon it passes through is a popular recreational spot which has long drawn large crowds of hikers and picnickers during the summer months. Legions of day-trippers once parked along both sides of the old two-lane road, which regularly choked up with heavy truck and recreational traffic, becoming both an annoyance and a hazard. For many years, efforts to improve the road were frustrated by a deadlock between engineers and environmentalists. The highway engineers, led by state highway director Charles "Blacktop Charlie" Shumate, favored a traditional "least cost" engineering design that would have virtually filled the bottom of the canyon with embankments and destroyed much of its scenic beauty. Environmentalists favored a more advanced—and much more expensive—design that would be less destructive. In 1975, after Blacktop Charlie retired, the two sides finally arrived at a compromise. Today, a four-lane divided highway runs through the canyon, much of it in tunnels or elevated. The designers spared no effort. Rock surfaces that had to be blasted were sculpted and then stained to match the surrounding terrain.

The new road is a thing of beauty, a wonderful example of what can be accomplished with genuine cooperation between environmentalists and engineers. But was it worth building? In the end, this 12-mile stretch of highway cost $490 million, or $41 million per mile. (Average costs for rural interstates today are $8–$10 million per mile.) Did the half-billion dollars spent on Glenwood Canyon create a half-billion dollars in benefits to the U.S. economy? That is the kind of question that must be faced in deciding what to build and where to build it.

Unfortunately, the planners and technical experts cannot provide the answers. Cost-benefit analysis, the favorite technique of economists, would seem to offer an obvious solution, but it is a highly uncertain art

even under the best of circumstances, and it is easily manipulated by opponents and advocates of particular projects. Simply estimating how much traffic a new road or rail line will attract, for example, is highly speculative. Some of the worst estimates have been made in mass transit. Miami, for example, began construction of a federally subsidized subway system in 1979 on the basis of an estimate that it would attract enough passengers to drive the cost per passenger trip down to $1.72. But the riders never came. In the end, even after accounting for inflation, it costs Miami (and federal taxpayers) an astounding $16.77 to carry every passenger, an error of almost 1,000 percent. What went wrong? Engineers and planners remain bitterly divided over whether the mistakes in Miami and other cities were the result of honest forecasting errors or efforts to bend statistics to win federal subsidies.

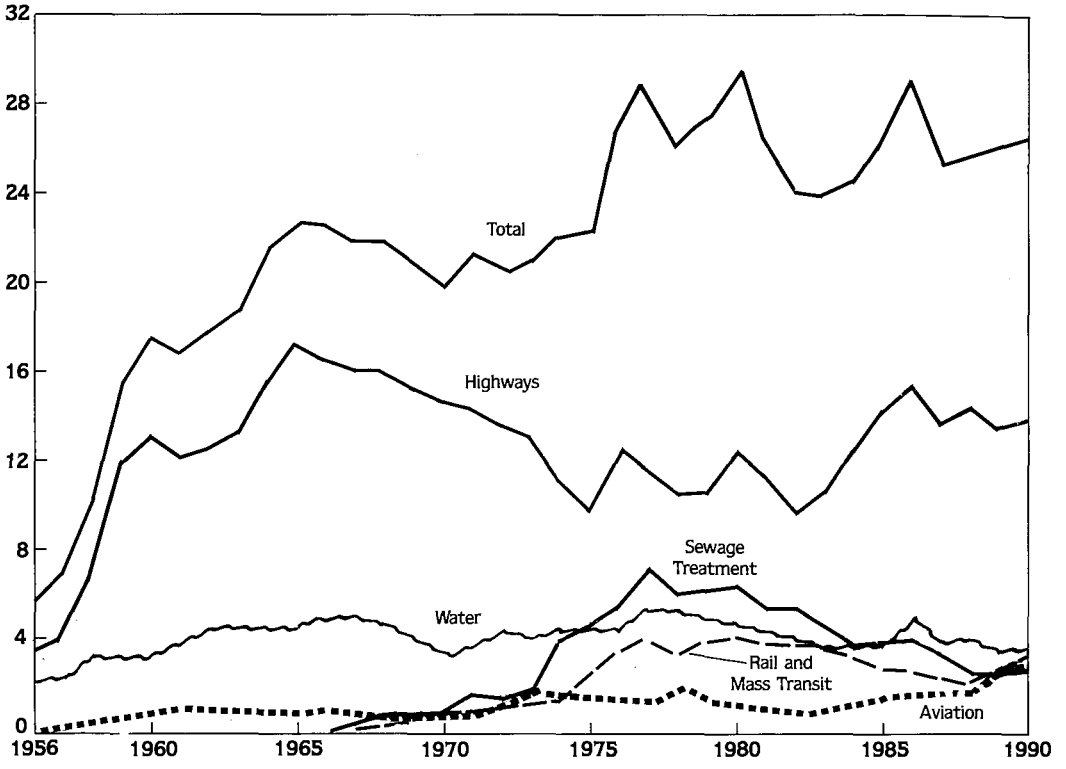
Infrastructure's productivity benefits are likewise very uncertain. Consider a simple example. Each of two towns separated by a river has a concrete-mixing plant and a grocery warehouse. With a bridge, the two towns together might need only one of each. The enlarged facilities would be more efficient than the old ones combined, so grocery and concrete prices could drop accordingly, benefiting the residents of both towns. But estimates of how much they will benefit—how much grocery and concrete prices will drop, for example—are very hard to make and are very easy for interested parties to manipulate and misrepresent. And of course they are subject to endless challenges in today's lengthy process of hearings, court proceedings, and public debate.

The inexactness of cost-benefit analysis creates terrible dilemmas for public officials. How are they to make rational decisions if not on the basis of benefits and costs? Private investors face similar dilemmas when considering an investment. Will it pay a reasonable return? Will a new product or service attract enough customers? Will the costs of producing a service end up exceeding the price it will command in the marketplace? But markets resolve such uncertainties quite differently, by using a tool that is extremely unpopular in the public sector: failure. Markets quickly recognize failure. A subway company that loses its shirt building and operating a system in Miami will not likely repeat its mistakes elsewhere. In the public sector, failure is harder to define, and public officials have every opportunity to delay the embarrassing recognition of costly mistakes by obscuring them in mountains of paper or explaining them away.

Most people are surprised to learn that market approaches have played an important role in the development of American infrastructure. The construction of the railroad system in the 19th century, for example, was largely carried out by private firms. America's $260-billion telecommunications infrastructure of copper and fiber-optic cables, switching systems, and satellites was also built largely through private investment, and in recent years private industry has wired 50 million American households with cable TV. Every year, electric utilities invest $10–$15 billion in new plants and equipment. In each case, government has played a significant supporting role of some kind. Generous land grants

Jonathan Gifford *is assistant professor in the Department of Public Affairs at George Mason University and a Senior Research Fellow at the university's Institute of Public Policy. He is now at work on a book entitled* Flexible Urban Transportation Systems.

FEDERAL INVESTMENT IN 'CORE' INFRASTRUCTURE*
(In billions of 1990 dollars)



*Capital outlays in categories such as energy, NASA, and veterans' hospitals are not included. These totaled some $10 billion in 1990.

Source: Congressional Budget Office

Creating jobs is the perennial justification for spending more on public works, but today's debate has been fueled by a new and more sophisticated argument. As the chart shows, federal investment in infrastructure has been stuck at roughly the same level since the mid-1970s. Measured as a share of gross domestic product (GDP), total spending (including state and local outlays, which dwarf those of Washington) has actually dropped, averaging only 2.4 percent of GDP. David Aschauer, an economist at Bates College, has seized on this decline to help explain the sluggish productivity growth that has afflicted the nation for the past two decades. His "Aschauer Curve" suggests that every $1 spent on public works yields up to $2 of additional GDP—an astounding number that led columnist Michael Kinsley derisively to compare the Aschauer Curve to the Laffer Curve.

Indeed, some of Aschauer's most vocal critics have been centrist and liberal economists. Henry Aaron of the Brookings Institution, for example, reluctantly dismisses Aschauer's findings as "just too good to be true." Aaron and others raise a host of technical objections to Aschauer's work. And they point out that even if his correlation between public works and productivity is correct, his conclusion is probably wrong. Public-works spending likely dropped *because* productivity growth (and thus economic growth) slowed, not the other way around. Moreover, while there was a momentary infrastructure "crisis" during the early 1980s, there is scant evidence today that many needs are going unmet, except in a few locales such as New York City. George Peterson of the Urban Institute, for example, notes that voters now approve nearly 75 percent of all state and local public-works bond referenda. While *certain* public-works projects can yield great benefits, the critics seem to agree, a massive program that raised the federal deficit and thus squeezed out private investment would do more harm than good.

aided the railroads, for example, and telecommunications giant AT&T was shielded by a federally sanctioned monopoly until 1984. The private sector provided the funds and did the construction, and the government set the framework for investment and return—and retained the right to alter the framework, as it did last fall when it re-regulated the cable-TV industry after numerous complaints about price-gouging. These are the models that should guide us in the 21st century. In such hybrid public-private efforts, government establishes the rules of the game, such as requiring that all environmental costs be factored into a project's price, and the private sector figures out what can be done within them. We must use market principles and information both to select projects to be built and to discipline infrastructure use. That means relying upon market prices.

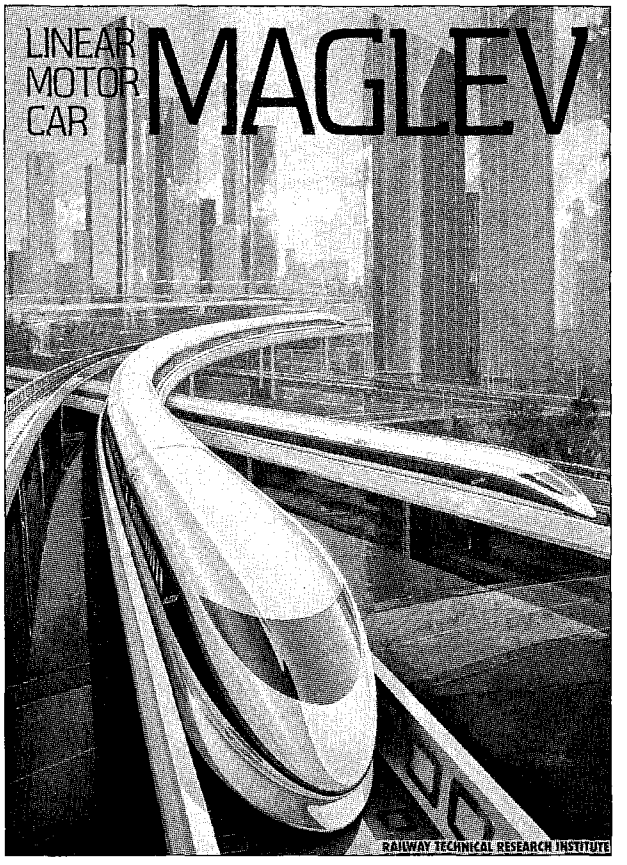
Highways offer some of the most exciting opportunities for the application of these principles. For centuries, tolls have provided a practical means of paying for roads, bridges, and tunnels, but in the automotive age their use has been restricted because toll booths are expensive to staff and operate and because they create intolerable traffic bottlenecks. New technology is beginning to overcome these disadvantages. Thanks to innovations in communication and computer technology during the past five years, tolls can now be collected without requiring cars to stop or even slow down. The vehicles are equipped with identification devices the size of a credit card, and sensors overhead or embedded in the road register the information and charge the toll electronically to the owner's account, just as if he or she had made a purchase with a credit or debit card. Such electronic toll-collection is now being used on the Oklahoma Turnpike and in several other locations in the United States and Europe. (Some old-fashioned toll booths are left in place to handle cars that lack the new technology.) In the New York metropolitan region, the major bridges and tunnels are being outfitted with similar equipment, as are four new highways in California.

These innovations may sound unexceptional, but the implications are enormous. Not least, the extinction of the congestion-inducing toll booth removes a major objection to more privately financed roads, tunnels, and bridges. And the ability to collect user fees efficiently opens up major new opportunities to address environmental and other problems. One of the four projects now being planned in California, for example, is a four-lane expressway to be built in the median of the Riverside Freeway with an intriguing state-mandated feature designed to increase carpooling and thus reduce the number of polluting vehicles on the road. The new road will be free to three- and four-person carpools, but cars carrying only one or two people will have to pay a toll. A variation on this scheme allows tolls to be based on tailpipe emissions, so that economic incentives can be focused on the small number of older cars that contribute disproportionately to auto air pollution.

Toll financing offers a number of other opportunities. One of the major expenses in almost all infrastructure systems is the provision of enough capacity to meet peak demand. Highways, for example, must be built with enough capacity to serve the morning and evening rush hours, even though they are usually underused the rest of the day and on weekends. Electric utilities, similarly, are forced to build enough power plants to meet the surge of demand that occurs on summer weekday afternoons when the use of air conditioners surges. This peak-hour capacity is the most

expensive to provide because it is used only at the peak. The rest of the time it must be serviced and maintained but lies idle. The improved control and fee-collection technologies now emerging from the laboratories will allow prices to adjust accordingly, making peak-time users bear their fair share of the costs and holding demand in check. For example, motorists who use urban expressways during rush hour will pay higher tolls. Some motorists will be deterred, thus lowering the demand for new roads. Those who still insist on driving during rush hour will wind up paying tolls that more accurately reflect their fair share of the road's true costs.

The peak-pricing principle has already been put into operation by some electric utilities and water companies here and abroad. The Potomac Electric Power company (PEPCO), which serves Washington, D.C., and its Maryland suburbs, has started a program called Kilowatchers that permits residential customers to save $7–$9 per month during the summer. PEPCO installs a radio-activated device that allows it to turn off the customer's air-conditioner compressors for 13 minutes out of each half hour on up to 15 summer afternoons. The program has been extremely popular; some 125,000 of PEPCO's 585,000 customers have signed up. PEPCO says that the ability to control peak demand has spared it the need to build a small $100-million generating plant.



A Japanese company's futuristic pitch for "bullet trains." Such trains, magnetically suspended above their tracks, now operate in Japan but are heavily subsidized.

The flip side of using pricing and user fees to regulate demand for infrastructure services is that the revenues they yield can be used to increase the supply of infrastructure—and to indicate where new infrastructure is not justified. During the economic boom of the 1980s, for example, the state of Virginia authorized a private corporation to build a $300-million toll road from the congested outer suburbs of Washington, D.C., near Dulles Airport to the growing town of Leesburg, 14 miles to the west. If built, the road would be the longest privately owned highway in America. The developers painstakingly assembled the needed right of way from private property owners, but in the interim, of course, boom has turned to bust, and the project has not yet attracted the needed financing. Would the toll road's failure show that private roads are not viable? On the contrary, it would illustrate one of their virtues. If it ap-

pears that there will not be enough future traffic to pay for the road, then the market will show that it should not be built. Capital is best invested elsewhere.

A host of other privately financed infrastructure projects are currently on the drawing boards or underway. In Orlando, Florida, a corporation has been granted a state franchise to build a magnetic levitation (maglev) "bullet" train line running from the city's airport to Disneyworld. Maglev trains, suspended above their tracks on a magnetically maintained cushion of air and capable of speeds approaching 300 miles per hour, may prove feasible in the United States for passenger transportation between cities up to 500 miles apart.

Bullet trains, along with fiber-optic "information superhighways" to link every computer in the nation, are a pet project of Vice President Albert Gore, Jr. His statements leave his intentions unclear. Gore says that he is "sensitive to avoiding any distortion of the marketplace," but he has also declared that Washington should intervene "when the marketplace seems to be ignoring essential facets of the infrastructure." To promote information superhighways, he has spoken of using federal money to start demonstration projects. "Once we find a technologically superior alternative, we have confidence that the market is quite capable of recognizing the opportunity and moving in that direction."

Relying on private capital in these and other areas would not magically resolve all of our conflicts over infrastructure projects. But a market approach allows a relatively quick and direct test of whether a project is financially feasible. In the Glenwood Canyon case, a market approach would have told us if the $490 million necessary to build an environmentally acceptable project was worth it. Maybe it was. Or perhaps it would have made more sense to ban trucks from the old road and ship container trucks over the Rockies by rail.

Among the people who make and analyze public policy, however, the virtues of market-based infrastructure development are not widely appreciated. Even those who accept the idea of user fees find it hard to resist the tempting notion of diverting the revenues to other projects—using toll receipts, for example, to underwrite mass transit. Experience shows, however, that users tend to regard such diversions as a new form of taxation, a perception that undermines the popular support needed to put user fees into practice.

The emphasis in the public sector is still mostly on expanding public control, and the latest trend is toward "demand management"—new regulations restricting the demand for infrastructure. This approach is seen in measures requiring utility companies to promote conservation among their customers, laws that make new housing construction contingent upon the availability of new roads and sewage-treatment plants, or outright bans (especially in the West) on using water to wash cars or water lawns. Advocates of this approach argue that there is too much gratuitous use of infrastructure, and they are right to a degree. Accurate pricing would provide the best solutions to such problems, but government agencies still often prefer to resort to traditional command-and-control techniques. The illusion is that these methods yield benefits without costs. In Los Angeles, for example, employers are now being encouraged to regulate the commuting habits of their employees by new laws that impose financial penalties on those that have "too many" employees driving solo to work. Employers are expected to organize carpools and take other steps to discourage

individual commuting. This idea may have a superficial appeal, but the hidden costs are considerable. The employer must divert resources from other productive uses to organize the car pools—perhaps hiring a coordinator—while workers must sacrifice either leisure time or work time to fit into the inflexible pool schedules. A pricing strategy that charged employees or their employers the full cost of transport would let people sort out these trade-offs for themselves, arriving at solutions that are more efficient—and freely chosen.

What market approaches have in common is flexibility. Whether the challenge is building new infrastructure or controlling demand for existing infrastructure, the market not only recognizes and adapts to changing needs but lets individuals and businesses find the best way to use what we already have. The reign of the expert has ended in public infrastructure, but our thinking remains firmly rooted in Enlightenment concepts of prediction and order, reflected in master plans and 20-year forecasts. Even the best laid plans have miscarried. The New Deal's Tennessee Valley Authority has done many things, but it has failed to transform the Tennessee Valley into a prosperous region. The interstate highway system, rightly celebrated for its contribution to national productivity, also did much harm. Many critics have blamed it for speeding the decline of American cities, but few have recognized that generous federal subsidies for interstates also stifled the building of the smaller urban highways that could have eased the gridlock that afflicts cities today.

It is not that government has no role to play. America has a long history of successful hybrid efforts. The public sector has been most effective when it has established a framework in which suppliers and users can figure out how a particular technology can be used productively. This may require creating a market, regulating rates, or some other effort to set the context for the private-sector response. Alice Rivlin, former director of the Congressional Budget Office, suggests a useful rule of thumb: If government must be the builder, responsibility should be left whenever possible in the hands of state and local governments. Not only can they muster the local political support needed to get projects underway, but with their own money at stake they are less likely to choose projects that do not make economic sense.

Building flexibility into our infrastructure will be one of the key challenges of the next century. The age calls for adaptability rather than adherence to rigid standards, a yielding of immutable hard rules to a recognition that in order to prosper one must quickly adapt to circumstance. The hierarchical corporation has evolved into the decentralized business; mass production is giving way to flexible manufacturing of customized products; one-industry cities such as Pittsburgh have been transformed into diversified regions. The character of the entire national economy is shifting, as manufacturing yields to the rising service sector, and as computers and advanced communication technologies revolutionize the production, consumption, and distribution of goods and services. It is difficult to predict exactly what kinds of infrastructure will be needed to provide the "technological sinews" of the future. But to be guided by nostalgic ideas about reconstructing the infrastructure of the past would be a terrible error, just as trying to employ the methods of the past would be. Only a flexible system that responds to changing market signals can effectively provide for this new era.

THE SAGA OF AMERICAN INFRASTRUCTURE

Until fairly recently, few historians paid serious attention to such seemingly humble matters as sewerage, solid waste, and stormwater management. Today a growing body of public-works history sheds valuable light not only on our contemporary infrastructure problems but on some of the basic forces that have shaped American life.

Much of this new scholarship followed the publication of **History of Public Works in the United States, 1776–1976** (Am. Pub. Works Assoc., 1976), by Ellis Armstrong, Michael C. Robinson, and Suellen Hoy—a comprehensive overview that is still the field's defining text—and the formation in 1975 of the Public Works Historical Society, which provided scholarly focus. Another essential work is **Technology and the Rise of the Networked City in Europe and America** (Temple, 1988), whose editors, Joel A. Tarr and Gabriel Dupuy, argue that infrastructure not only facilitates but guides life in the industrial "networked city."

Those who despair over the institutional "gridlock" that hampers the building of infrastructure today will find some comfort in Christine Meisner Rosen's **Limits of Power: Great Fires and the Process of City Growth in America** (Cambridge, 1986). Building infrastructure has always been "a slow, difficult upward struggle," the Berkeley historian concludes. Even in the wake of catastrophic fires in Chicago (1871), Boston (1872), and Baltimore (1904), American cities made only limited progress. The Baltimore blaze, for example, "gutted 86 city blocks containing 1,526 buildings, burning out more than 2,400 businesses." The reformers who controlled the city government saw the fire as a "golden opportunity" to fix longstanding problems: traffic-snarled streets, inadequate water and sewer systems, hazardous electric wires overhead, and the decay of the Inner Harbor. But as the various costs of the city's ambitious redevelopment plan became clear, support fragmented. Businessmen, property owners, workers, and others who would be hurt by street widening, for example, turned against the idea. In the end, Rosen writes, the city was able to accomplish a great deal but some major problems, such as the decline of the waterfront district, continued to fester.

Taking a longer view in **The Urban Millennium: The City-Building Process from the Early Middle Ages to the Present** (Southern Illinois, 1985), Michigan State University historian Josef W. Konvitz argues that infrastructure before the 1880s was shaped chiefly by economic considerations and produced "environments ill-prepared to adjust to many of the changes accompanying urban development." Since then, decisions in the modern industrial city have been controlled largely by bureaucratic organizations, special authorities, and regulatory bodies; but thanks to uncoordinated planning, results have been little better than those before the 1880s.

The birth of modern city planning is usually traced to the First National Conference on City Planning and the Problems of Congestion in 1909. But Stanley K. Schultz, a historian at the University of Wisconsin, Madison, argues in **Constructing Urban Culture: American Cities and City Planning, 1800–1920** (Temple, 1989), that its roots lie in the 19th century, when Americans haltingly began to think of themselves as an urban people and civil engineers and others began to ponder ways of coping with growing urban ills. Planning streets, sewers, and the like was not merely a matter of efficiency and economy to these reformers, Schultz stresses. As a New York City alderman put it, "A proper city plan has a powerful influence upon the mental and moral development of the people." After the Baltimore fire of 1904, for example, an engineer arguing for construction of a new sewage system pointed to Paris, "the center of all that is best in art, literature, science, and architecture," claiming that "in the evolution of this ideal attainment, its sewers took at least a leading part."

The engineer may have exaggerated the benefits of a good sewage system, but there is no question that new forms of infrastructure can have a transforming effect. **The Electric**

City: Energy and the Growth of the Chicago Area, 1880–1930 (Chicago), by Harold L. Platt of Loyola University, tells the story of one such transformation. The human drama of construction on a massive scale is captured in Joseph E. Stevens's **Hoover Dam: An American Adventure** (Okla., 1988), a lyrical account of the five-year, around-the-clock labor by some 5,000 men working under grueling conditions that produced this futuristic edifice on the Colorado River during the 1930s.

The rise of the suburb also owes much, for better or worse, to developments in infrastructure. In rapidly growing Chicago, new suburbs during most of the 19th century sought to be annexed by the city in order to gain city water service, sewer lines, and other amenities, observes Ann Durkin Keating, a historian at North Central College, in **Building Chicago: Suburban Developers and the Creation of a Divided Metropolis** (Ohio State, 1988). But toward the end of the century, when suburban land developers began offering "urban conveniences," as the promoters of Riverside, Illinois, promised, along with "the special charms... of rural conditions of life," there was a shift toward suburban autonomy from the older city.

The interstate highway system likewise contributed to the rise of suburbs, and it has been scrutinized by a number of scholars. Bruce E. Seely's **Building the American Highway System: Engineers and Policy Makers** (Temple, 1987), shows how an alliance of state and federal highway engineers was able to foster a belief in "apolitical expertise" that allowed them to shape, if not control, highway policy. **Interstate: Express Highway Politics, 1939–1989** (Tennessee, 1990), by Mark Rose examines the origins of the interstate system. Yet historian Paul Barrett of the Illinois Institute of Technology argues in **The Automobile and Urban Transit: The Formation of Public Policy in Chicago, 1900–1930** (Temple, 1983) that, in Chicago at least, the mass-transit systems that were the lifeblood of the big city were doomed in part by local decisions made without much thought long before the interstates were built. In Chicago, it was assumed by the 1920s that the privately owned streetcar system should pay for itself but that planning for the auto was "a duty of local government."

Other scholars have begun to turn their attention to the connection between public works and the environment. **Garbage in the Cities: Refuse, Reform and the Environment, 1880–1980** (Wadsworth, 1988), by Martin V. Melosi of the Univerity of Houston, for example, places the problem of solid-waste disposal at the center of early environmentalism. The industrialization of the ecology of the Great West is the subject of William Cronon's **Nature's Metropolis: Chicago and the Great West** (Norton, 1992). Cronon, a Yale historian, argues that the penetration of the natural landscape by the railroads that fanned out from Chicago beginning in the 1850s literally remade the face of nature. Chicago, he writes, became "the link that bound the different worlds of east and west into a single system." Rail links to Chicago encouraged farmers to plow under the prairies to grow wheat and corn for sale in Chicago and eastern markets. They likewise spurred the growth of the cattle industry in Texas and of logging in the north. Chicago and its infrastructure, Cronon writes, were responsible for nothing less than the creation of a "second nature" in the American West.

In these and other works, scholars have made a great deal of progress toward understanding the lessons of the past. History suggests that those who plan and build public works should shift their thinking from a crisis-to-crisis approach to a longer-term view. The studies also underscore the importance of creating flexible plans that can be adjusted to changing circumstances. Casual assumptions must be questioned. And there is a need for greater sensitivity to local economic, political, and cultural conditions. But the most urgent need is to deliver the knowledge we now have to the people who are planning and building tomorrow's infrastructure.

—Howard Rosen

***Howard Rosen** is Director of the Public Works Historical Society. He has written and edited many books, including* Water and the City: The Next Century *(1991) and* The States and the Interstates *(1991). Readers who want more information on the history of public works may write the PWHS, c/o the American Public Works Association, 1301 Pennsylvania Ave. N.W., Washington D.C. 20004.*