Economic Perspectives on Infrastructure Investment

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ABSTRACT

To determine the appropriate level of infrastructure spending, there is no alternative to aggregating the results of project-by-project cost-benefit analysis. With widespread variation in both the benefits and costs of projects within broad infrastructure asset classes, it is important to recognize that the returns to some additional highway lanes are much higher than others, and that the costs of extending wire-line broadband coverage in some locations may exceed the benefits relative to the next-best alternative technology. Because comprehensive project evaluation is enormously information-intensive and can be gamed, many of the widely discussed estimates of the infrastructure gap in the United States are based on alternative methodologies, such as benchmarking infrastructure spending levels against international or historical averages. Such exercises may not recognize that infrastructure projects in the United States often cost more than arguably comparable projects in other nations. As infrastructure spending ramps up, heightened attention to procurement practices and to project management could yield high returns in avoiding unnecessary spending. Cost-benefit calculations must also consider maintenance spending as an important infrastructure outlay, since the bias of the political system toward ribbon-cuttings for new projects can often short-change high-return upgrade and maintenance work. Financing infrastructure is a perennial challenge. User fees, while politically difficult to adopt, can be an important way of ensuring that infrastructure is used efficiently and of aligning

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funding with those who reap the benefits of new projects. With a few exceptions, such as public transit buses, infrastructure use is progressive. In cases in which user fees may be regressive, it may be possible to design compensatory policies, such as transit system vouchers for low-income households, to offset distributional concerns while preserving the efficiency benefits of use-related charges. Public-private partnerships require careful analysis on a case-by-case basis. While they can deliver operational and procurement benefits relative to similar projects managed exclusively by the public sector, they can also impose unpriced risks on taxpayers, and in some cases can impose a long-term increase in the cost of infrastructure use in return for a short-term relaxation of public sector liquidity constraints.

1. Introduction

Both sides of the political spectrum routinely call for increased public spending on infrastructure projects, although their justifications often vary. Federal support for infrastructure now seems likely to ramp up in the near future, although the spending plan's size, timing, financing and scope are not finalized. The prospect of a major infrastructure initiative makes this an appropriate time to review a number of economic insights related to such spending.

All infrastructure projects are not created equal, and the benefits per dollar spent can vary widely as a function of the nature of the project and the management of its construction and subsequent use. Different projects will benefit different constituencies, both geographically and across the economic spectrum, so infrastructure projects must be viewed as one part of the federal government's activities that impact the distribution of economic resources.

This paper highlights policy relevant lessons from the voluminous research literature on the economics of infrastructure projects. We provide a selective introduction to the many studies on the topic and draw a number of conclusions that can inform the design of an infrastructure-spending program, regardless of its size or scope. Four conclusions deserve particular note.

First, because infrastructure projects differ widely in cost, complexity, and benefits, systematic cost-benefit analysis is a critical tool for identifying the highest-return opportunities. Studies of the return to expanding the interstate highway system, for example, point to very different benefits in different locations. The highest value derives from expansions in densely populated areas with congested roadways—but those are also often the most expensive places to build new highways or expand existing ones. While it is difficult to draw firm conclusions about the optimal size of a federal infrastructure initiative from existing research, the rigorous application of cost-benefit analysis can help direct spending to the highest return-for-cost projects. A number of studies suggest high returns to maintaining existing infrastructure. Comparing the returns to new projects with those on maintenance initiatives is a key component of any high-return infrastructure program.

Second, managing costs is essential for any infrastructure project. Building highways and subways is, by some indicators, significantly more expensive in the United States than in other high-income countries. Several potential factors may explain these high costs: infrastructure design, the extent to which the project must remediate potential adverse effects on communities and the environment, and construction management, starting with procurement and including the way delays and cost over-runs are handled. The best time to address these issues is before, rather than after, launching a major infrastructure spending initiative.

Third, user fees can play an important role in financing both new infrastructure projects and in maintaining existing ones. User fees are often ruled out in the policy process because they are claimed to be regressive. More honestly, they are politically difficult. Yet fees for vehicle miles traveled that vary by time of day, for parking in dense urban areas, for the use of airports and ports, and many other user charges can reduce the demands that an infrastructure program places on general revenues. If set to reflect the marginal cost of using infrastructure, they also represent an important step toward its efficient utilization. While there are many justifications for investing in infrastructure, there are few compelling reasons for making such infrastructure free to users, especially since that will lead to utilization above and beyond the efficient, cost-reflective level. Overuse of transportation infrastructure is not just economically inefficient, but can have other adverse effects, such as the generation of excessive carbon dioxide emissions and other forms of pollution.

Finally, while public-private partnerships and the privatization of infrastructure assets can sometimes enhance operational efficiency and improve both procurement and management, private provision also creates risks. At times, private providers have negotiated, or in some cases renegotiated, highly advantaged terms, or failed to serve key constituencies. Privatizing infrastructure assets as a means of raising capital warrants particularly scrutiny. It is only attractive when the private sector can secure funds on more favorable terms than the public sector, but the U.S. Treasury borrows at a particularly low rate and most state governments also have excellent bond ratings.

The remainder of this paper describes the evidence that leads us to these four conclusions and elaborates on them. We begin by identifying key features of traditional, or physical, infrastructure assets. Then we describe various approaches to assessing the appropriate level of infrastructure investment and to undertaking cost-benefit analyses. Next, we discuss the cost and financing of infrastructure projects. Finally, after describing some of the political economy challenges that arise in infrastructure projects, we address the potential role of the federal government in a more localized process of project selection and implementation.

2. Defining features of physical infrastructure projects

The term "infrastructure" is a relatively recent addition to our national vocabulary, and its meaning has evolved over time. Carse (2016) explains that it was originally used by engineering writers to describe railroad tracks, which were a "piling up" (*structura* in Latin) below (*infra*) steam trains. The first appearance of "infrastructure" in an English language economics journal appears to be Wellisz' (1960) article on Dutch, French and Italian economic development. He put the term in quotations and defined it to be synonymous with social overhead capital, investments that lowered costs for their users, while also delivering static externalities as well as dynamic externalities by encouraging private investment. When Joy (1967) used the term, it remained sufficiently esoteric to require definition, in this case as a "synonym for 'track' in its broader sense of earthworks, bridges, tunnels, permanent way and signage." In the last half century, "infrastructure" has expanded well beyond the railroad sector, but in most contexts it still refers to various types of fixed capital investments. In an influential study, the Congressional Budget Office (1988) referred to "public works infrastructure" and identified six sub-categories: highways, aviation, mass transit, wastewater treatment, water transportation, and groundwater and surface water resources.

The American Jobs Plan, when proposed in March 2021, included spending on public works, or "traditional" infrastructure, as well as new outlays to retrofit homes and private commercial buildings, provide job training, increase R&D spending, and improve access to child and elder care. Spending programs in these categories are often labeled "social infrastructure."

This paper focuses primarily on traditional infrastructure projects that involve fixed capital investments associated with the movement of goods—including electricity and digital content—or people. This definition encompasses all of the CBO's public works infrastructure, as well as broadband, fiber optic cables, and the electricity grid. Our focus on these topics should not be interpreted as a dismissal of the importance of social infrastructure spending. Such spending can be enormously valuable. However, the issues in the design and analysis of such spending programs are different from those associated with traditional infrastructure programs.[1]

To introduce our focus on physical infrastructure projects, we highlight four important features that are found in nearly all of them and that are central to their analysis:

1. ***Project valuation depends on future use.*** Predicting future use is essential to evaluating a potential infrastructure project. Use is determined by demand from potential users and by the supply of complementary inputs. For instance, rails have little value without trains,

[1] In some cases, the line between traditional and social infrastructure blurs. For example, while we do not discuss investments in hospitals or schools, neither of which are involved in moving goods or people, either could be included in traditional infrastructure, while also playing a key role in the provision of social infrastructure.

and highways are less valuable when the cost of vehicles or fuel are high, or when there is little parking available at potential destinations.

2. ***Projects generate location-specific benefits.*** Infrastructure projects typically generate benefits to users in a particular place. A fixed geographic location makes infrastructure, such as a rail line, riskier than other investments, like buses, that can be moved to adapt to changing circumstances. The place-based nature of infrastructure also implies that its beneficiaries are geographically concentrated, which means that it will have particular appeal to place-based politicians, and as a potential source of aid for disadvantaged places. Infrastructure investment may have direct benefits for a location, and it may also spur complementary private sector investment. Infrastructure investments can also generate negative externalities, such as road noise, that harm particular neighborhoods.

3. ***The marginal cost of facility use is often below the average cost of service delivery.*** Traditional infrastructure is a fixed investment, and the marginal cost of using it may be less than the average cost of building and maintaining it. That gap is a potential justification for government subsidies. Measuring the marginal cost of use is not always straightforward—especially when there are significant costs of congestion, accidents, pollution or when the depreciation rate of the physical capital depends on its use. These components can be much more difficult to assess then simple operating costs**.**

4. ***Projects are long-lived.*** Nearly all infrastructure projects involve both immediate costs and future benefits This raises issues about how to appropriately discount future benefits and costs, and makes the choice of a discount rate a key policy lever. The decline in real interest rates in the last three decades should be reflected in this process. In addition, inherent uncertainty about the future makes it difficult to accurately value the costs and benefits associated with any particular project. Uncertainly also means that flexibility is a desirable feature of long-lived infrastructure projects. For instance, some roads can take a variety of vehicles, while railroad tracks have limited applicability. More flexible infrastructure projects should command a lower risk premium than inflexible projects, since they can adapt more easily to technological or economic change.

Most infrastructure projects involve a period of investment, followed by a much longer period of use. This means that the timing of the investment period can matter. Advocates of fiscal stimulus see infrastructure as a natural tool for employing underutilized labor and capital during a downturn. Skeptics retort that infrastructure takes so long to plan and implement that most recessions will be over before meaningful work gets done. Recognizing and addressing these lags is essential if infrastructure spending is to be used as a tool of macroeconomic stabilization.

3. What determines the optimal level of infrastructure investment?

The initial proposal for the American Jobs Plan called for $932 billion of spending on traditional forms of infrastructure, including transportation ($621 billion), water ($111 billion), broadband ($100 billion) and the electric grid ($100 billion). Some call for even larger outlays: the American Society of Civil Engineers (ASCE) (2021) claims the United States needs nearly $2 trillion in spending to close its 10-year infrastructure-investment gap. What determines the optimal level of infrastructure investment, and the optimal size of the infrastructure capital stock? These are difficult questions to answer, and it is easier to describe an approach to answering them than to provide a specific answer.

The guiding economic principle is clear: the optimal level of infrastructure should be determined by comparing the costs of acquiring infrastructure capital with the benefits of using it. Benefits can be difficult to measure, however, and projected and completed project costs often diverge. This section describes several approaches to assessing the optimal level of infrastructure capital and the returns to infrastructure investment. It contrasts the "engineering" approach, which defines infrastructure need without emphasizing the trade-offs between marginal costs and marginal benefits, and the economic approach, which embraces them.

3.a. A collision of paradigms: engineering vs. economics

One of the most widely cited studies of the state of the U.S. infrastructure capital stock, which is commonly invoked in support of higher spending levels, is the ASCE's *Report Card for America's Infrastructure*. It assigns the United States a grade of C- for 2021. Another study by the McKinsey Global Institute (MGI), summarized by Woetzel et al. (2016), finds that "the world needs to invest an average of $3.3 trillion annually just to support currently expected rates of growth." Both studies determine infrastructure need by reference to standards, in the ASCE case engineering standards, and in the MGI case historical spending levels, that do not consider the cost of infrastructure investment. The implicit premise of the ASCE study is that "need" equals that cost of bringing all infrastructure capital up to best-practice engineering standards. Particularly in the case of upgrading currently safe and functional infrastructure that does not meet current design standards, some comparison of costs and benefits seems more appropriate.

Unlike engineers, who are often asked what it will cost to build a bridge but not asked to measure its benefits, economists are rarely asked to determine the cost of a bridge, but they are often asked whether the benefits of building it compare favorably with other potential uses of the public funds that building the bridge will require. Lionel Robbins famously defined economics as "the science which studies human behavior as a relationship between ends and scarce means which have alternative uses." It is difficult for an economist to consider infrastructure spending as a fixed requirement that must be satisfied before allocating funds to health care or education or national defense.

The economic approach to assessing the optimal level of infrastructure capital is project-driven. It begins by estimating returns on investing in a particular project and comparing them with its cost. Provided the costs include the distortions associated with tax finance or other funding mechanisms, and that there are no constraints on raising additional revenue, the decision rule "if benefits exceed costs, accept the project" will generate the set of projects that warrant public investment. If there is a fixed budget available for infrastructure investment, it may not be possible undertake all projects for which benefits exceed costs; in that case investment should flow to projects in the order of their benefit-cost ratio.

This approach, which endeavors to include benefits to users and to society as a whole, typically yields a list of high- and low-return activities. Gramlich (1994), an example of the application of the economic approach, presents a ranking of potential projects. In this framework, the optimal level of infrastructure spending equals the sum of the cost of all the projects for which benefits exceed costs. Importantly, the estimate of need would depend in part on economic parameters, such as the costs of inputs like steel and concrete, the construction wage rate, and the level of interest rates. If costs of construction rose, the optimal number of infrastructure projects to undertake would decline. If interest rates and discount rates fell, holding all else equal, the warranted level of infrastructure spending would rise, because the future benefits of infrastructure projects would be valued more highly relative to their current costs.

3.b. How are widely cited estimates of infrastructure "need" constructed?

To frame the discussion of the optimal infrastructure capital stock, it is helpful to understand how two of the most widely cited studies of infrastructure need develop their estimates. The ASCE analyzes the current infrastructure capital stocks in a variety of different asset classes, and compares them with measures of need and engineering best practice. The ASCE *Report Card*, which estimates the spending needed to raise the nation's grade to an "A," are often thought to measure the level of spending required to preserve the safety and soundness of transportation and water infrastructure. That is not the case; the infrastructure grades target a different benchmark.

When ASCE refers to an infrastructure asset as structurally deficient, that does not mean that it is unsafe. In fact, "structural deficiency" is a more technical term. An asset can be classified as structurally deficient because it does not meet all of the current standards for constructing a new asset of the same type. In the case of a bridge, it may receive a structural deficiency label because of substantial water traffic delays at high tide. The CBO (2016) explains that "bridges with structural deficiencies have significant parts in a deteriorated condition and reduced load-carrying capacity. Bridges that are functionally obsolete do not meet current design standards.… Neither type of deficiency necessarily indicates that a bridge is unsafe." In addition, the grades assigned to various infrastructure classes depend on a number of subjective elements, such as the degree of innovation in infrastructure planning and construction, and the robustness of the funding plan by the government entity that is responsible for maintaining the asset. An infrastructure class may lose marks because of organizational weaknesses in the entity that oversees assets in that class, not because of limitations in the physical condition of the underlying assets. Such considerations may be relevant for discussions of infrastructure financing and governance, but the low grades do not necessarily reflect the quality of existing physical infrastructure.

The ASCE also assumes, implicitly, that the only way to remedy an infrastructure deficiency is by building new capacity (*e.g.,* reducing daily congestion on a particular roadway by adding more lane-miles). Taken on its own terms, the highway congestion example illustrates the shortcomings of defining infrastructure need by setting a fixed target, such as the absence of congestion. Calculating the reduction in congestion-hours on a particular road segment that will flow from a given road-building program is difficult, in part because highway lane supply creates its own demand. Duranton and Turner (2011) find that the amount of driving increases dramatically with the number of road miles built. Even assuming that it was feasible to expand the highway network enough to sharply lower traffic delays, the underlying goal of traffic-free roads is not the same as determining the optimal stock of highway capital. Why do we think that spending enough to get traffic-free roads is the best use of government funds relative to other uses of public funds, such as investing in early childhood education?

In contrast, a key element of the economic approach is recognizing that capital spending is only one way of addressing a given objective. There may be others. The same outcome that could be achieved by building additional highway lanes could also be achieved by adopting sophisticated time-of-day congestion pricing on the most-demanded routes, as some cities, such as Singapore, have done with some success. The optimal size of the infrastructure capital stock is likely to be smaller if utilizing the capital is priced rather than free. Engineering estimates of infrastructure need are likely to be overstated because of the failure to consider more efficient use of existing infrastructure assets. Cost-benefit analysis should be used to choose among the different approaches to reducing congestion.

Moreover, transportation innovations, like ride-sharing services, automated vehicles, and GPS-based road pricing, provide additional alternatives to public infrastructure. For example, instead of building train links to underserved populations in low-density locales, the poorer residents of those places could be provided with vouchers for ride-sharing services. An experimental program that allocates such vouchers, or combines mobility vouchers with Section 8 housing vouchers, could facilitate measuring the impact of such services. GPS-based road pricing can reduce congestion even more effectively than traditional tolls. Autonomous buses on dedicated lanes can move swiftly between cities and offer a plausible alternative to rail that is far less expensive.

While some of the infrastructure spending that is identified in the ASCE *Report Card* can perhaps be viewed as a "need," much is discretionary, and should be subject to standard cost-benefit analysis. Even for some decisions that may appear to be binary, such as whether or not to repave a road, there is often a continuous decision component, such as when to repave. Cost scales with the frequency of repaving. The timing of spending on new roads, bridges, and tunnels is flexible, yet this is not reflected as a consideration in the ASCE analysis.

Because the engineering analysis of infrastructure is a technical task, it can be difficult for nonexperts to find independent metrics to evaluate the ASCE grades and to thereby assess the spending recommendations. One example of where such a comparison is possible is road quality. The Department of Transportation (DOT) collects International Roughness Index (IRI) for U.S. roads. Relatively comprehensive data on U.S. roads are available since 1993. The ASCE awarded U.S. roads a "D" grade in both 2017 and 2021, up from D- grades in 1998 and 2009 but down from a C+ grade in 1988 and a D+ grade in 2001. Yet Duranton, Nagpal, and Turner (2020) observe that for at least one important class of transportation arteries—interstate highways—road roughness has improved over time.

Table 1 shows that for urban interstates, the percentage of miles of highway (distinct from percentage of miles driven on the highway) that is in the smoothest category has risen from 3.5% in 1993 to 40% in 2019. The share of smooth rural interstate road-miles increased from 8.3% to 53.4%. Interstate highways account for about 2.5% of U.S. roadway lane-miles but nearly one-quarter of all miles driven. Yet despite these significant improvements, the ASCE grade for highways fell from a C+ in 1988 to a D- in 1998. Road smoothness increased dramatically from 2009 to 2019, and yet the ASCE raised its assessment by only one-third of a grade.

Table 1: Roughness of U.S. highways, 1999–2019

Road Type and Roughness Measure	1993	1999	2009	2019
Rural, IRI > 170	12.5%	12.6%	10.5%	12.5%
Rural, IRI < 60	6.2	9.5	12.0	16.3
Urban, IRI > 170	18.5	28.0	29.9	33.0
Urban, IRI < 60	4.0	9.0	9.1	8.0
Rural Interstates, IRI > 170	7.0	2.3	1.7	2.0
Rural Interstates, IRI < 60	8.3	21.5	34.0	53.4
Urban Interstates, IRI > 170	13.2	7.3	5.1	5.0
Urban Interstates, IRI < 60	3.5	12.0	20.9	40.1

Source: Authors' calculations using DOT Condition of U.S. Roadways by Functional System data as reported at https://www.bts.gov/content/condition-us-roadways-functional-system, accessed 5/31/2021. Rural and urban roads are divided into various categories (interstates, other principal arterials, minor arterials, and major collectors (rural) and collectors (urban)). The entries in rows 1-4 weight the IRI results for each category based on the number of road-miles in that category.

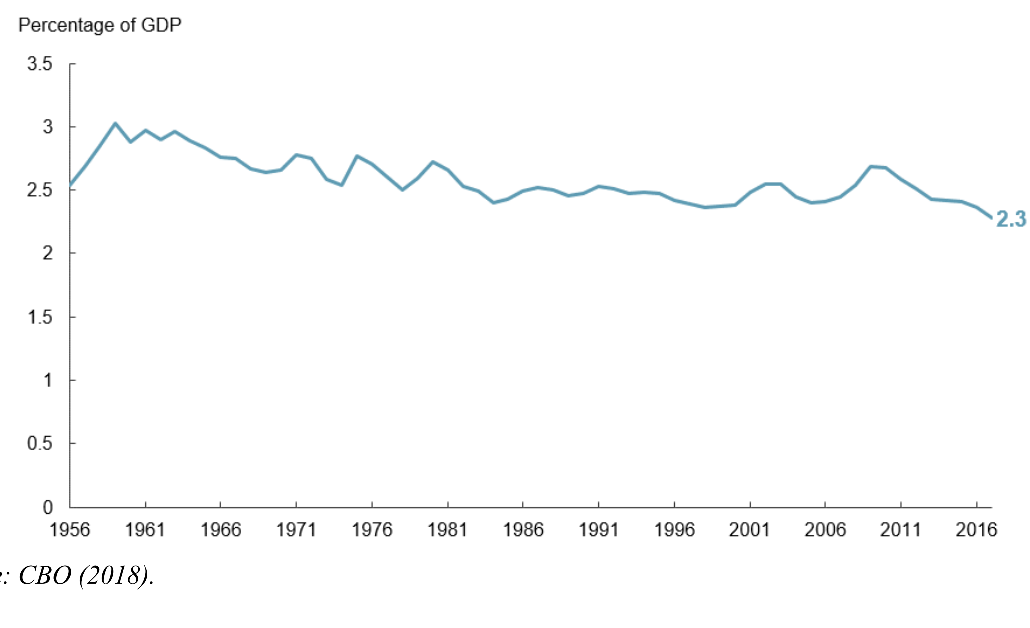
Bridges have also seen significant improvements in the last two decades, but only a slight increase in their ASCE grade. In 1998, the Federal Highway Administration reported that 6.9%

of the bridges that were classified as part of the National Highway System (NHS), and 16.5% of all bridges, were structurally deficient. ASCE assigned bridges a C- grade that year. By 2017, the share of bridges classified as structurally deficient had been cut in half, to 3.4% of the NHS bridges and 8.9% of all bridges. The ASCE grade rose only modestly, however, to a C+.[2]

While ASCE is probably the most widely discussed study of infrastructure need, another frequently cited source for infrastructure need is the McKinsey Global Institute (MGI). MGI adopts three approaches in assessing infrastructure need; none compares infrastructure benefits with infrastructure costs. The first uses historic spending patterns, as a percentage of GDP, for each country. Woetzel et al. (2016), who summarize the MGI findings, calculate that "historical spending pattern indicates that global investment on roads, rail, ports, airports, power, water, and telecommunications infrastructure has averaged about 3.8% of global GDP." If this 3.8% is multiplied by global GDP projections through 2030 from IHS Global Insight, which are based on an assumed 3.3% annual growth rate, total global infrastructure spending "need" equals $62 trillion from 2013 through 2030.

Figure 1 shows the time series pattern of U.S. spending on transport and water infrastructure as a share of GDP. From a high of nearly 3% of GDP in the late 1950s, when the interstate highway system was being built, the level of spending has trended down, reaching about 2.3% of GDP in recent years.

Figure 1: Public spending on transport and water infrastructure, 1956–2017



Source: CBO (2018).

[2] FHWA data on bridges may be found at https://www.fhwa.dot.gov/bridge/nbi/no10/defbr17.cfm (accessed July 01, 2021). Historical values of the ASCE Infrastructure Report Card are available at https://infrastructurereportcard.org/making-the-grade/report-card-history/.

Cross-country comparisons indicate that the United States is currently a low-spending nation with regard to transportation investment. Table 2 shows that in 2019, transportation infrastructure investment as a share of GDP in France, Germany, and the U.K. was higher than that for the United States, at 0.89%, 0.89%, 0.71%, respectively, as compared to 0.55% in the United States. China spent 5.64% of GDP on transportation investment, but the comparison is difficult because China is building infrastructure from a much lower base than other countries. Cross-country comparisons are very difficult to evaluate because of this initial condition issue, and because the costs of investing in infrastructure may different across countries.

Table 2: Transportation infrastructure investment, share of GDP, 2019

Country	Inland Transportation Investment/GDP
China	5.64%
France	0.89
Sweden	0.89
Germany	0.71
U.K.	0.91
U.S.	0.55

Source: OECDiLibrary, Total Inland Transportation Infrastructure Investment, 2019, per GDP, stats.oecd.org, accessed 5/31/2021.

The MGI study also employs a second approach to estimating the optimal stock of infrastructure capital: assuming a desirable ratio of the value of infrastructure capital to GDP, based on historical patterns. While this approach is based on the stock of capital rather than the flow of new investment, it suffers from the same limitations as the historical, investment-as-a-share of GDP analysis. It does not consider either the current costs, or current benefits, of modifying the infrastructure capital stock. MGI reports that the infrastructure stock for most economies averages about 70% of GDP. Under the assumption that this reflects some long-run optimum, the study then calculates the amount of annual spending needed for infrastructure to reach and remain at that level. Globally, this calculation suggests that $67 trillion of infrastructure investment is needed between 2013 and 2030. This approach, which yields a similar answer to that from the spending-as-a-share-of-GDP analysis, also suffers from similar shortcomings. The first references the average historical flow of spending, and the second, the average historical stock of infrastructure capital. If the stock were constant as a share of GDP, however, the observed flow of spending would indicate the level of spending needed to maintain that stock. The stock approach and the flow approach could only diverge if the stock was rising or falling significantly during the historical period being studied, as it would be, for example, in China. For the United States, with a relatively stable infrastructure capital-to-GDP ratio, the two approaches unsurprisingly yield estimates of infrastructure need that are very similar.

The MGI approach provides an uncertain guide for the appropriate level of future spending, because there is little guarantee that spending in the past was at the right level. Indeed, much of the discussion behind an infrastructure agenda assumes that the United States has been spending too little. While applying spending ratios from other nations to the United States suggests substantial infrastructure need, it is not obvious that the ratio of infrastructure spending to GDP should be the same in the United States as it is other countries with lower per-capita income. Optimal infrastructure spending is likely to be higher when a highway system is being first laid down, as it was in the United States in the 1950s and 1960s, than when that highway system is mature, as it is today. A backward-looking or cross-country comparative approach also neglects potential differences, over time or across nations, in the cost of building infrastructure. The United States today faces higher costs of construction than other developed nations, which could translate into a smaller optimal infrastructure capital stock than elsewhere.

The third approach to estimating the optimal level of infrastructure in the MGI study relies on third-party estimates of future asset-class-specific infrastructure demand. Estimates are drawn from the Organization for Economic Cooperation and Development (OECD), the International Energy Agency (IEA), and Global Water Intelligence (GWI). The OECD's numbers are "central projections … derived from a Reference Scenario, based on a set of assumptions about government policies, macroeconomic conditions, population growth, energy prices and technology." These projections are not derived from any cost-benefit framework, and they embody important assumptions about future policies, in particular with regard to regulations related to climate change and the evolution of the energy economy. These figures are best understood as estimates of the amount of infrastructure needed to deliver the future quantities of electricity, water, and transportation services that their models predict will be needed.

Neither the ASCE estimate of the spending needed to raise infrastructure grades, nor the MGI estimates of infrastructure gap, answer the question: for how many infrastructure projects does the project cost fall below the best estimate of the project's benefits, and how much will it cost to invest in all those projects?

3.c. The cost of meeting infrastructure needs: lead pipes, safe bridges, and robust dams

For some categories of infrastructure, estimates of "need" are accompanied by the observation that those elements of infrastructure can fail catastrophically if they are not maintained. The most commonly emphasized threats are collapsing dams, falling bridges, and lead poisoning from aged pipes. While these risks are real, the amounts needed to reduce them are only a small part of the aggregate infrastructure needs that are currently reported.

ASCE suggests that over the next two decades, the United States needs to spend $109 billion ($2019) per year on water infrastructure to close the water infrastructure gap. Yet, as Tabuchi (2017) reports, the one-time cost for replacing a pipe is approximately $5,000 and there are approximately 10 million lead pipes remaining in the United States. That number fits closely with the $45 billion budgeted for lead-pipe removal in the American Jobs Plan.[3] This represents a one-time outlay that is less than one-half of the annual spending the ASCE recommends. Much of the additional spending may apply to water infrastructure with more modest benefits than lead pipe replacement.

With regard to bridges, the DOT reports a disturbing rise in the number of bridges in poor condition. Deadly bridge collapses were more common in the 1980s than in recent years, but in 2007, 13 people died in the collapse of the I-35 bridge in Minneapolis.[4] The DOT (2019) estimates that an annual investment of $12.9 billion is necessary to maintain the current condition and performance of U.S. bridges, and suggests $22.7 billion as the proposed spending level to generate improvement, a value that ASCE cites uncritically.

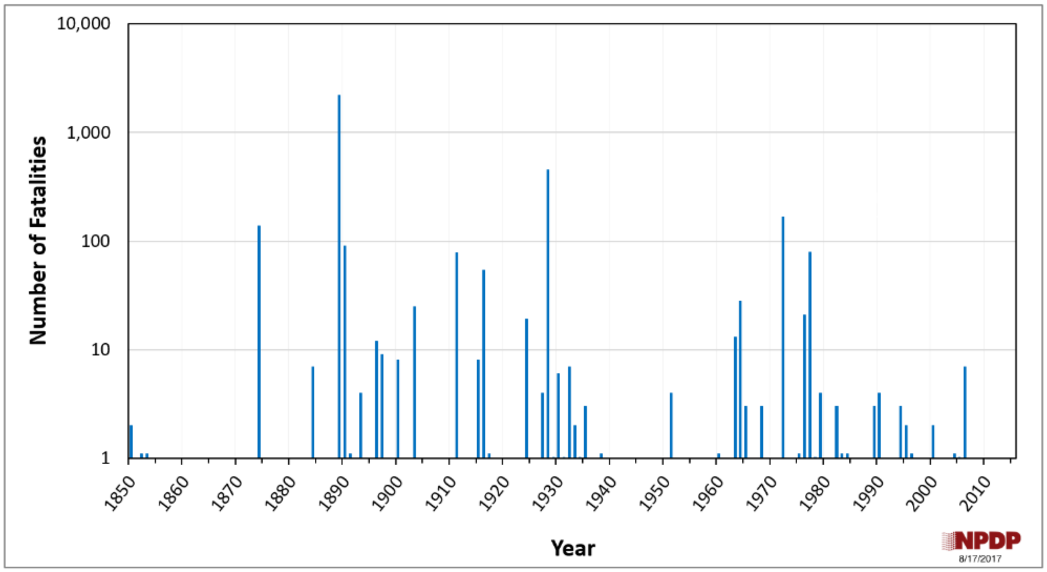
The initial American Jobs Plan proposed $115 billion to upgrade the roads and bridges that are in most critical need of repair. The difference between the DOT's recommendation, $22.7 billion, and current spending is about $8.3 billion of spending per year, so a $115 budget for bridges could fund such an increase for nearly 14 years. Moreover, the DOT report does not indicate that this level of spending is needed to avoid catastrophic collapse, only that it would "improve conditions and performance."

Like bridges, dams present a risk of catastrophic failure. While the Johnstown Flood that followed that failure of the South Fork Dam killed thousands of downstream residents in 1889, recent dam failures have involved far fewer fatalities. Over the past 30 years, "dam failures" have typically meant water overtopping dams, such as Michigan's Edenville Dam (in 2020) and Iowa's Delhi Dam (in 2010) due to heavy rains, and they have rarely been deadly. The biggest near miss occurred in 2017 when 180,000 people were evacuated from areas downstream of the Oroville dam in California, but the dam held (KCRA 2017).

Figure 2 shows the number of dam fatalities by year in the United States in each year since 1850.

[3] These funds are supposed to be given to the Environmental Protection Agency to add to its Drinking Water State Revolving Fund and to disburse the Water Infrastructure Improvement for the Nation grants. This fund and those grants, as currently specified, do many things beyond replacing lead pipes.
[4] Many of the deadliest bridge disasters involve the collapse of pedestrian bridges (Penn 2018).

Figure 2: Timeline of fatal dam failures, United States



Source: Stanford University National Performance of Dams Program, accessed 5/31/2021 at http://npdp.stanford.edu/consequences_fatalities.

While the potential risks from dam-related catastrophes are real, the Association of State Dam Safety Officials (2017) estimates that rehabilitating all federally owned dams would only cost $4.2 billion, with $2.9 billion of that amount targeted to "high hazard" dams. Over two-thirds of all dams are owned by the private sector, and for them, the costs of rehabilitation are estimated to be much higher: $60.7 billion, with $18.7 billion devoted to "high hazard" dams. Presumably, the federal government's role should be to provide regulatory oversight and safety inspections, and then require the private owners to pay for maintenance. The relevant budgetary cost in this case, for inspections and enforcement, is likely to be a small fraction of the cost of dam repairs.

3.d. Universal wired broadband vs. alternatives?

The COVID-19 experience of remote schooling strengthened the case for investing in broadband in lower-density parts of the United States. Even before the pandemic, rural broadband access was on a sharply rising trajectory, due both to private market initiatives and public subsidies. The Federal Communications Commission (FCC, 2021) reports that at the end of 2019, 94% of Americans lived in areas with access both to 25/3 Mbps fixed broadband service—what the FCC defines as high-speed broadband—and 10/3 Mbps mobile broadband service. Between 2016 and 2019, the number of rural residents lacking access to 25/3 service fell 46%. In 2019, 17% of rural residents did not have access to such service.

Public policy has been subsidizing rural broadband since the 1996 Telecom Act, which taxed telephone calls to finance rural broadband subsidies (Greenstein 2021). The Connect America Fund, established in 2011 by the FCC, subsidizes the development of rural high-speed broadband at a cost of $4.5 billion per year (Boik 2017). There have also been sporadic bursts of investment in broadband for lower-income individuals or lower-density areas, such as the 2009 American Recovery and Reinvestment Act.

A key question is whether, for those who do not currently have access to 25/3 Mbps service, delivering such service requires fiber optic cable access, which can be expensive to provide to some remote areas, or whether other technologies, such as satellite broadband or 5G network access, can serve as a cost-effective alternative. The benefit-cost ratio for the three technologies is likely to vary by place, with fiber optic installation more expensive per household in very remote, low-density areas, and 5G only feasible in some areas with favorable local topography for line-of-site transmission. Boik (2017) examines a subsidy for broadband adoption in North Carolina and finds that many households seem to find satellite broadband an attractive alternative to high-speed wired broadband. He finds that "fewer than 43% of households adopt high-speed broadband in areas currently served by a single broadband provider," and relatively low willingness to pay for high-speed broadband among significant numbers of households that currently use slower options, DSL, or satellite. He concludes that "at most 64% of unserved census block regions in North Carolina warrant an entry subsidy to provide broadband quality comparable to urban areas," and that the cost of bringing high-speed broadband to households in the least dense 5% of the state would only be warranted if these households valued this service at more than $1500 per month.

Current satellite broadband speeds are now fast enough for most conferencing software applications, although since satellite data plans are typically less generous, full time students may run up against hard data walls. These data caps could cause hardship for families living in low-density areas if schools shift to online learning during another future emergency. Nonetheless, these financial shortfalls could be met with school-based subsidies, which might be much less expensive than a complete rural build-out of high-speed wired broadband. If high speeds are deemed to be essential, a central question is whether satellite broadband is fast enough. The satellite provider Viasat offers a 100 Mbps download speed plan. If that option meets other technical needs, then the high costs of providing hardwire broadband should be compared with the costs of subsidizing high-speed satellite service in remote areas. As with pricing infrastructure services as an alternative to building more infrastructure, multiple approaches to achieving the overall policy objective—in this case high-speed internet access—should be considered. Either alternative should be subject to standard cost-benefit analysis, the topic we now consider.

4. Cost-benefit analysis and infrastructure spending decisions

The application of project-specific cost-benefit analysis to individual infrastructure projects, and the aggregation of the results, is quite different from a budgeting process that seeks to come up with an aggregate spending number and then to enact legislation to spend that amount.

Theoretically, it would be possible to do cost-benefit analyses on a vast number of projects, select only those projects with benefits greater than all-inclusive cost of raising the relevant funds, and to add the cost of those projects up to produce an optimal level of infrastructure spending. Yet that is not the way resource allocation decisions for infrastructure operate at present. In this section, we will briefly review the application of cost-benefit analysis to infrastructure projects, and then discuss ways in which that analysis might play a larger role in policy discussions going forward.

A key but not surprising insight of the project-based, bottom-up cost-benefit analysis approach, rather than the top-down, aggregate spending target approach, is that there is likely to be substantial heterogeneity in the returns to different projects within an infrastructure category. Just as subsidizing satellite broadband in some remote areas may offer a better cost-benefit trade-off than building fiber optic lines, some unsafe bridges in areas that attract relatively little traffic may be better closed and demolished than rebuilt. The cost of rebuilding may exceed all reasonable estimates of the return.

The starting point of cost-benefit analysis is calculating benefits by projecting the future uses of the infrastructure, evaluating the value of those uses, and then discounting that benefit flow using an interest rate, such as the government's cost of funds, adjusting as needed for risk. The benefits are then compared with the project's cost, which typically involves a large up-front cost as well as future periodic maintenance outlays, which must also be predicted and discounted.

While there is near universal endorsement of cost-benefit analysis among economists, it is not the cornerstone of infrastructure policy analysis. The time involved in estimating the returns to any one project are significant, and that makes the cost-benefit approach unattractive to anyone trying to craft legislation quickly. Moreover, cost-benefit analysis involves considerable uncertainty and inevitably, the evaluator has opportunities to exercise discretion. It is important to try, where possible, to develop institutions that can perform non-partisan, rigorous cost-benefit calculations. The public may, appropriately, be skeptical of estimates of the benefits of a bridge over a 30-year horizon. Cost-benefit analysis is often most useful when the gap between benefits and costs is large, which means that the project clearly should or should not be funded.

4.a. Cost-benefit fundamentals

There are a number of features of cost-benefit analysis that are similar across many forms of physical infrastructure. We identify six such components, and describe each of them with reference to transportation infrastructure projects.

4.a.1. Estimating future benefits.

The first ingredient of cost-benefit analysis involves estimating future usage of the infrastructure, and the benefits that flow to each user. In a standard private sector investment decision, payments to the investment's owner, such as profits on a business or royalties on a patent, are the benefits to the investor. Since users of publicly funded projects can often access them at a nominal cost, the benefits to users are usually assumed to be greater than the ticket price. Cost-benefit analyses in the transportation sector have been plagued by erroneous predictions for decades, with project boosters often overpredicting future expected demand (Kain 2007). Conversely, costs have frequently been underestimated, often by a wide margin. The rosy $35 billion projection of the cost of high-speed rail in California, made by the engineering firm Parsons Brinckerhoff in 2014, is a high-profile example (Parsons Brinckerhoff 2014). The next year, that firm won a $700 million contract to provide management services related to the high-speed rail system (Railway Technology 2015). By 2021, the estimated cost had reached $100 billion (Vartabedian 2021). While the mis-estimate may have been entirely innocent, engineering firms that stand to benefit from building infrastructure may have a conflict of interest when reporting on the benefits and costs of that infrastructure.

4.a.2. Measuring systemic impacts

A second ingredient of cost-benefit analysis for transportation projects involves measuring the impact of a new project on the usage of other routes and modes of transportation. A new rail line may alleviate the traffic on highways. Estimating the links between different modes, or even different routes within a given mode, is an even more difficult problem, one that can require sophisticated analytical tools. For example, Allen and Arkolakis (2019) develop a network model and estimate the system-wide benefits of building new highway capacity. Their results, shown in table 3, find particularly high benefits to adding new highway lanes in some parts of the New York metropolitan area, which would seem to argue for more construction there, but they have limited information on the costs of adding new lanes in that area. More generally, their analysis highlights the range of benefits relative to costs for highway construction. There are of course many projects with much lower benefit-cost ratios than those in table 3, including numerous projects with values less than one. The application of the network model illustrates the need, in some cases, for detailed analytical work that goes beyond the proposed project. Developing the capacity for that, perhaps with a federal infrastructure bank, could be an important part of an infrastructure initiative.

Table 3: Examples of high benefit-cost ratios for additions to interstate highway system

Project Location	Estimated Benefits ($M /year)	Estimated Costs ($M/year)	Benefit-to-Cost Ratio
White Plains, NY to Greenburgh, NY	$510.5	$3.8	135.8
North Hempstead, NY to Queens, NY	719.5	5.4	134.5
Islip, NY to Brookhaven, NY	257.5	1.9	135.5
Indianapolis, IN	206.9	2.2	100.4
Bayonne, NJ to Staten Island, NY	179.9	1.9	93.7

Source: Allen and Arkolakis (2019).

4.a.3. Assessing ancillary benefits and costs

A third step in cost-benefit analysis involves studying and evaluating the ancillary benefits of changing travel patterns. For example, new infrastructure spending might affect the total amount of carbon emitted in the United States, and the direction of the effect is likely to depend on the nature of the projects supported. The American Jobs Plan emphasizes investments that might reduce carbon emissions. Achieving that goal through new infrastructure requires a strong degree of substitution between new, low-carbon forms of transportation and older, more traditional modes. The degree of such substitution is an open question. A new rail line might reduce carbon emissions if it leads to reduced car traffic. Baum-Snow, Kahn, and Voith (2005), however, find that the train-for-car substitution is modest at best, which implies that the carbon emitted in building the rail line and in operating it every day may result, on net, in an *increase* in carbon emissions. To calculate the ancillary benefits of infrastructure construction that accrue through environmental channels, the estimated change in carbon emissions from new infrastructure must be multiplied by the welfare cost of carbon emissions. The precise magnitude of this cost is a subject of active debate (Stern and Stiglitz 2021).

4.a.4. Estimating macroeconomic effects

A fourth component involves measuring the macroeconomic effects of infrastructure projects, such as anti-recessionary stimulus and agglomeration economies. While infrastructure spending is often advanced as a job-creating program, there is uncertainty about the number of jobs that are created by each dollar spent on infrastructure, and about the social value that should be placed on such jobs. One estimate, using data from the American Recovery and Reinvestment Act (2009), is that $200,000 of infrastructure spending creates about one job for one year, while the spending is going on, although there is considerable uncertainty about that figure (Garin 2019). The jobs-per-infrastructure dollar ratio is likely to vary with the type of project and with the broader economic conditions that prevail when the project is undertaken.

The macroeconomic community is split about the value of infrastructure as a tool for fighting recessions. There are long-standing concerns about the capacity to time infrastructure spending to coincide with periods of economic slack. The prospect of long and variable lags in the implementation of fiscal policy, including infrastructure spending, was an important factor in the shift from fiscal to monetary policy as a primary tool for macroeconomic stabilization in the decades prior to the global financial crisis. The costs of labor can be lower in recessions, although often not by much, and that suggests that ordinary cost-benefit analysis should push infrastructure construction toward downturns. However, as long as the employment impacts of infrastructure spending remain uncertain, it will be difficult to resolve the differences between the advocates of counter-cyclical infrastructure spending, such as Summers (1988, 2017), and those who see minor macroeconomic effects at best, such as Ramey (2021).

It is also difficult to estimate the intrinsic benefits of job creation, which come from reduced spending on government-provided unemployment benefits as well as from personal benefits such as improved self-esteem. A reasonable approach to estimating these benefits involves multiplying three numbers: (1) the projected number of workers on the project; (2) the increase in total employment per worker hired, which captures the degree to which infrastructure employment crowds out other employment, and (3) the social benefits of switching workers from nonemployment to employment. The estimates of Garin (2019) and others indicate that even in a recession, public infrastructure employment significantly crowds out private employment, so the increase in employment per worker hired is likely to be far less than one.

4.a.5. Measuring impacts on GDP and productivity

A fifth element in cost-benefit calculations is the project's impact on economy-wide output and productivity. These effects are distinct from the jobs created in building the new project. New infrastructure may enhance the productivity of businesses, thereby raising total output. These benefits are linked primarily to use of the project, making it particularly important to accurately assess the prospective utilization. New infrastructure may also cause a relocation of economic activity that generates local externalities, such as agglomeration effects, which are benefits that accrue when firms and people locate near one another, thereby reducing transportation costs. Some evaluations of transportation infrastructure include agglomeration effects, which occur when an increase in the scale of a community increases the output of each of its members. London's Crossrail, for example, was supposed to create large-scale agglomeration benefits (Bhasin 2007). Yet if infrastructure projects just move people and activity from one area to another, then there will be offsetting agglomeration losses in the shrinking place, which must be weighed against the agglomeration benefits from the expanding area. Glaeser and Gottlieb (2009) argue that there is little economic certainly about the magnitude of these different effects.

4.a.6. Considering distributional impacts

A final component of cost-benefit analysis is the recognition of the distribution of project benefits and costs across the population. The standard approach is to treat benefits to one group as equivalent to benefits to another, and to sum the net benefits across groups. Alternatively, however, losses to vulnerable populations can be treated as far more serious than benefits to the prosperous. A dollar lost by the poor could be treated as the equivalent to two dollars gained by the rich. A job created in a low-income neighborhood could be valued more than a job created in a high-income location. Of course, such group-based weights must reflect moral and political values, not economic estimates, but cost-benefit analysis can always provide a range of estimates depending on the weights that are assigned to different populations. Similarly, it is possible to weigh losses more heavily than gains for all groups. The cost-benefit framework is flexible and can accommodate a wide range of social values.

As critical as cost-benefit analysis may be, there is little chance that a project-by-project analysis can be undertaken in the short time available when legislators begin debating a national infrastructure bill. This is surely one of the reasons a top-down, select-a-budget total approach is more common. One way to address this challenge is to maintain ongoing cost-benefit analysis in relevant federal agencies, such as DOT. Another, which can capture some of the benefits of cost-benefit analysis, is to apply this approach after the budget total has been determined. While the budget total may not be the same as the one that would arise from bottom-up cost benefit analysis, the allocation of the funds across projects will target those with the highest estimated benefit-to-cost ratio.

4.b. Expanding the role for cost-benefit analysis in the policy process

There are three ways in which cost-benefit analysis could be inserted more directly into the process of allocating U.S. infrastructure spending, even if bottom-up cost-benefit analysis is not possible. One is to focus on estimates of the benefits of infrastructure spending as a whole, rather than the benefits of particular projects. Increasing national spending on infrastructure makes sense when benefits per dollar spent are greater than the social cost of raising one dollar in taxes. The second is the creation of an infrastructure bank that would receive some fraction of federal infrastructure spending and deliberately allocate the funds to projects that appear to have particularly high benefits relative to costs. The third option would require states to make more use of cost-benefit analysis when they spend federal dollars, perhaps with input from a federal agency that develops and applies cost-benefit methods.

4.b.1. Applying cost-benefit analysis to overall spending levels

The first option is essentially "macro cost-benefit analysis." Instead of trying to figure out the impact of an individual bridge or highway, this begins by estimating the social benefit of spending an incremental amount, say $1 billion, on infrastructure overall or on a particular type of infrastructure such as highways. While this approach cannot ensure that all infrastructure projects deliver benefits greater than their costs, as long as future project choices resemble past ones, this approach provides a way for determining the return on new infrastructure spending.

There is a substantial literature on the aggregate output and productivity effects of infrastructure spending.[5] Estimates of the link between infrastructure spending and productivity are not precise, however, and many such estimates are confounded by the potential endogeneity of infrastructure spending. Furthermore, determining the causal effect of infrastructure on economic growth is not easy to do. If states spend on infrastructure in anticipation of future growth, then it might look like infrastructure is causing growth, even though it is the anticipation of growth that is causing the spending. If other state attributes, such as lower density levels, that are associated with more

[5] Pioneering studies by Aschauer (1989) and Munnell (1990) found a significant positive correlation between infrastructure capital and economic activity, while calling attention to the potential endogeneity of infrastructure spending. Shirley and Winston (2004), Gramlich (1994), and the CBO (1988) report that early post-war infrastructure investments had large returns, but that the returns on subsequent investments have been lower. Bom and Ligthart (2014) review the literature on infrastructure capital and aggregate output. Schanzenbach, Nunn, and Nantz (2017) summarize several recent empirical studies of how infrastructure affects productivity. Ramey (2021) includes infrastructure capital in a neo-Keynesian macro model, finding only modest productivity and output effects.

spending exert an independent pull on economic activity, then empirical estimates will also be misleading.

There is another difficulty with this approach: Economic activity does not automatically represent social benefit. A dollar of GDP is not a dollar of extra welfare, since presumably there was some cost, such as the workers' time, of producing that GDP. Moreover, local GDP, which is often the outcome used in empirical analyses of infrastructure productivity, can increase because activity is displaced from one area to another. Estimates of infrastructure productivity based on local outcomes may tell us very little about aggregate economic activity.

4.b.2. Creating an infrastructure bank or adopting cost-benefit mandates

Even if cost-benefit analysis cannot provide a number for optimal overall infrastructure spending, the tools of cost-benefit analysis can be used to allocate appropriated funds across different projects. There are two natural ways to use these tools to improve the targeting of spending. The first possibility, which was originally proposed by Senators Chris Dodd (D-CT) and Chuck Hagel (R-NE) in 2007 and was much discussed during the late Obama administration, is for infrastructure spending to be allocated by a national infrastructure bank that would use cost-benefit analysis. The second possibility is to require cost-benefit analysis before states are granted federal funds for new infrastructure projects.

The basic idea of an infrastructure bank is to establish an independent entity with some form of appointed leadership, possibly subject to Senate confirmation, that would oversee a significant amount of infrastructure spending. A national infrastructure bank would have similarities to the World Bank or the Asian Development Bank. These institutions specialize in funding projects that are typically implemented by some other entity. In the U.S. context, states, localities, and public-private partnerships would ultimately be in charge of implementation. If sufficient resources were devoted to new infrastructure investments, it would be possible for the infrastructure bank to develop a robust cost-benefit analysis process, and to use the results of that process to determine funding. The bank could carry out cost-benefit analysis and determine which projects should be funded from a pool of resources provided by Congress. That would amount to ranking potential projects and funding the highest benefit-to-cost projects until funding is exhausted. Additionally, the infrastructure bank could provide guidance to legislators on the level of infrastructure spending that might be warranted by high benefit-to-cost projects, the result of ongoing analysis of potential projects. The entity would have some discretion for allocating spending, but its key objective would be to fund those projects with the highest level of net benefits. The track record of the international entities should motivate caution about the capacity of independent "banks" to always target the highest value-added projects. That objective could be written into law, but ultimately the entity's leadership would need to be selected so that they shared that objective. An infrastructure bank also might, more easily, time its spending to coincide with downturns (Haughwout 2019).

An alternative way to expand the use of cost-benefit analysis is to continue with the current procedure of providing funds to states and allowing them to make allocation decisions, but to subject them to cost-benefit related requirements. For example, new projects might have to meet a fixed internal rate-of-return threshold in order to go forward with federal support. Requiring cost-benefit analysis for the maintenance of existing infrastructure makes less sense; there is more consensus about the high rates of return for maintaining the existing infrastructure stock.

In this model of state autonomy checked by federal oversight, cost-benefit analysis must be done by an independent entity. If these regulations were to be imposed on states, the federal government would need to create and fund an agency capable of appraising state projects. The CBO provides one model of such an entity. Presumably, the evaluation organization would have close ties to the DOT, but it would ideally be sufficiently independent and apolitical so that its judgments would carry widespread respect. All cost-benefit analysis is subject to gaming, since assumptions about inputs are critical to the outcomes. When those who provide the estimates of costs and benefits are able to inflate the former and understate the latter, the results of the analysis may not result in an appropriate ranking of potential projects. Rather than selecting the most attractive projects, the use of cost-benefit analysis may only identify the projects with proponents with the greatest proclivity to overstate benefits relative to costs.

An infrastructure bank, or a federal requirement for state cost-benefit analysis, would run into some potential challenges. The infrastructure bank creates more executive branch discretion and therefore carries more risk of mismanagement, both in itself and because it needs to work through other entities, like state governments. If states are choosing and administering their own projects, the basic incentives are better aligned. When state governments are spending a fixed sum of money, they face stronger incentives to keep costs down than if they are spending the funds of an infrastructure bank. Of course, it may be possible for the infrastructure bank to design incentive contracts that restrict waste and abuse.

An infrastructure bank might have the additional effect of catalyzing public-private partnerships, a topic we will address in more detail below. Some states, like California and Texas, have been far more aggressive than others in supporting public-private partnerships, and a state-level approach might not make much headway in states that have been reluctant to adopt this approach. One important worry, which emerges from the work of Engel, Fischer, and Galetovic (2014), is that private companies have incentives to, and often succeed in subverting government agencies. The legislature would need to remain vigilant to ensure that the national infrastructure bank was not captured by related private companies.

With regard to cost-benefit analysis mandates, while there is an added cost of carrying out expanded cost-benefit analysis, and there could be delays in launching projects until such an analysis was complete, it seems difficult to object to requiring simple cost-benefit analyses for new federally funded transportation projects. The costs of these analyses are very low relative to the costs of infrastructure. Cost-benefit analysis might still permit some white elephant projects to go forward, but it is likely to be an improvement relative to the status quo. Imposing rate-of-return requirements may be difficult to do, however, in a way that passes constitutional muster. Another limitation is that such a process would not determine the allocation of funds across states, although it might be possible to use the results of start-level cost-benefit analysis to inform Congressional debates on allocation.

An infrastructure bank has more upside and downside risk than cost-benefit analysis mandates. In principle, it could be a nimble and intelligent agency that chooses really high return projects throughout the United States. It could also become a political tool that is largely beholden to pet ideas of both legislators and the administration.

5. The cost conundrum for new infrastructure projects

Much of the discussion around the need for additional infrastructure focuses on the benefits from additional investment. The optimal amount of infrastructure capital is also a function of its cost, and by international standards, infrastructure projects in the United States are extraordinarily expensive. The basic logic of cost-benefit analysis thus suggests that the United States should, all else equal, have less infrastructure that other comparable nations. If fixing potholes is more expensive in the United States than in other countries, one would expect to find more potholes here.[6] Given the high cost of U.S. infrastructure projects, even large increases in spending may have only modest effects on the quality of infrastructure services. Two key questions are therefore why infrastructure construction costs are so high in the United States, and whether it is possible to reduce them.

5.a. Why does it cost so much to build infrastructure in the U.S.?

Flyvbjerg, Bruzelius, and van Wee (2008) compare the capital costs for urban rail projects around the world. The costs for the six systems in the United States that were included in the analysis range from $88 million per kilometer (Atlanta) to $147.5 million per kilometer (Baltimore). Thirteen out of 17 of the European systems in the study, and five out of six in Asia or Latin America, had costs below $88 million per kilometer. Levy (2011) argues that these comparisons understate the cost disadvantage of U.S. projects, noting that "the American projects examined are quite old, from the 1980s, and many have large above-ground parts." He further identifies three New York City projects with costs of $1.3 billion, $1.7 billion, and $4 billion per km, as well as San Francisco's Central Subway, which cost $500 million per kilometer even though, as a light rail tunnel, it was a less demanding project.

Levy's updated Transit Cost database reports actual or projected cost-per-kilometer data, converted to $US using purchasing power parity exchange rates, on 540 different projects,

[6] However, this logic does not imply that the United States should *spend* less than other nations on infrastructure—spending is the product of the price of infrastructure and the quantity purchased.

including 256 that were completed by 2020. We inflation-adjust these cost estimates using the CPI and assume that the median dollar was spent in the year that was half-way between the start and end date of the project. We treat projects with average years beyond 2021 as having an average year of 2021.[7] Table 4 presents our findings.

For the 19 projects in the database that are in the United States, the average cost was $1,601 million per mile, compared with a non-U.S. global average of $478 million. The median U.S. project was $965 million per mile, compared with a non-U.S. median of $299 million. The database also contains information on the share of the rail system that is underground. When we restrict our analysis to the 255 projects that are 100% in tunnels, the median cost of the 11 U.S. projects is $1,379 million per mile, compared with a non-U.S. global median of $341 million. While precise comparisons are difficult, many projects in densely populated foreign cities have substantially lower per-mile costs than their U.S. counterparts.

There is no widely accepted source of global comparative data for highway costs, but one analysis finds that the United States has the highest highway construction costs in the world (Brooks and Liscow 2021). U.S. highway construction costs have also risen over time. "Spending per mile on Interstate construction increased more than three-fold (in real terms) from the 1960s to the 1980s," a finding that is particularly remarkable because "neither changes in the observed geography of spending nor increases in material and labor prices explain these changes" (Brooks and Liscow 2019). The DOT National Highway Construction Cost Index increased by 32%, relative to the CPI, between 2003 and 2020.

Table 4. Cost-per-mile of large U.S. urban transit projects

City	Project Name	Start Date	End Date	Cost/Mile ($M)
Seattle	U-Link	2009	2016	637
Los Angeles	Purple Phase 3	2020	2027	1379
Los Angeles	Purple Phase 2	2018	2026	920
Los Angeles	Purple Phase 1	2014	2023	758
Los Angeles	Regional Connector	2014	2022	966
San Francisco	Central Subway	2010	2021	1115
Boston	Green Line Extension	2013	2021	523
San Francisco	BART to San Jose	2022	2030	1157
New York	7 extension	2007	2014	2921
New York	Second Avenue Phase 1	2007	2016	3156
New York	Second Avenue Phase 2	2019	2029	4271
New York	East Side Access	2007	2022	7081
New York	Gateway	2019	2026	2885

[7] This assumption seemed reasonable to us since estimates of future costs frequently fail to incorporate inflation. Levy uses the middle of the state and end year for his purchasing power adjustments.

Honolulu	HART	2011	2026	528
Los Angeles	Crenshaw/LAX Line	2014	2021	266
Miami	Metrorail extension to MIA	2009	2012	253
Seattle	West Seattle and Ballard	2026	2036	1045
Washington	Silver Line Phase 1	2009	2014	304
Washington	Silver Line Phase 2	2013	2021	264

Note: The original source, https://transitcosts.com/data/, reports cost estimates in current dollars. All estimates have been converted to 2021 dollars.

The high costs of U.S. infrastructure can be analyzed at two levels: in an accounting sense, by asking which items add so much to the bill, and at a deeper level, by asking why the prices of some inputs are particularly expensive. These analytical approaches can be applied to consider the costs of the single most expensive project in the Transit Cost Database: New York City's East Side Access project. This completely underground project, at $4 billion per kilometer, is more than 20 times more expensive than the average all-tunnel project in other countries. Barone, Vitullo-Martin, and Pichardo (hereafter BVP, 2018) dissect the high cost of that project as well as the Second Avenue Subway and the #7 line extension, also in New York City. The two other projects are less expensive than East Side Access, but at $2 billion and $1.8 billion per kilometer, respectively, in inflation-adjusted terms, they are still ten times more expensive than the global median for urban rail projects.

East Side Access' $12 billion costs, as of 2016, included $9.7 billion of construction costs, expansively defined. These include what BVP (2018) categorize as construction ($7.3 billion), construction and production management ($890 million), design and engineering ($660 million) and vehicles and spare parts ($800 million). The other $2.3 billion reflects finance charges ($1.12 billion), unallocated contingency money ($720 million), administrative and regulatory costs ($259 million), and real estate and relocation ($192 million).

The cost breakdown highlights a number of important patterns. First, real estate costs are a tiny share of the project's total cost, despite New York City's sky-high property prices. Second, neither administrative and regulatory costs, nor the even smaller category of environmental mitigation (contained within construction and only $2.14 million) were significant causes of the high costs. Third, the two largest elements in construction costs were tunneling ($3.1 billion) and stations and intermodal facilities ($2.3 billion). The very expensive station construction is one reason why East Side Access was the most expensive project in the database, but the tunneling on its own is extraordinarily costly by global standards.

While direct environmental mitigation itself was a small component of the accounting costs, environmental factors play a much larger role in the overall cost of the project by changing the nature of construction itself. For example, BVP (2018) explain that "the Environmental Impact Statement (EIS) required construction activities in Manhattan to take place in the subterranean realm, with almost all equipment and spoils transitioning through the 63rd Street tunnels to staging sites in Sunnyside Yards," which typically meant "laborers filling burlap bags with spoils that were then loaded onto trains to Queens (or in some cases, the Bronx) and then unloaded and sorted by laborers." The Metropolitan Transit Authority (MTA) estimated that it could have saved $75 million in schedule-related costs alone by deploying a simpler system similar to that used in other projects.

Labor costs and procurement problems seem particularly critical in contributing to higher expenses associated with East Side Access.[8] New York City pays its infrastructure workers very high wages. BVP (2018) estimate the minimum labor costs for electricians at $127 per hour, for tunnel workers at $102 per hour, and for cement and concrete workers at $57 per hour. Labor costs would be higher on Sundays. The total labor costs on the project were between $2.9 and $4.3 billion. With regard to procurement, BVP (2018) report that "the contractual history of [East Side Access] is replete with examples of practices and decisions that led to unnecessary delays, defaults, and costs." They highlight in particular the decision by the MTA in 2012 that "all bids on Contract Modification 12 (CM12) were too high, upward of $950 million." This led to the cancellation of the bids. MTA then divided the work in CM12 into three sub-projects, which caused a delay that BVP (2018) estimate at three years, and a cost increase of at least $373 million overall.

Bosio et al. (2020) examine highway procurement globally, and find that in poorly governed countries, strict procurement rules lead to less corruption and better outcomes. They find the opposite in well-governed countries, where procurement rules limit the ability of project managers to avoid problematic companies who offer low bids. In New York City, the MTA strictly adheres to a low-bid rule. BVP (2018) note that "the adherence to accepting only the lowest qualified bid has led to less-experienced contractors defaulting on contracts."

The East Side Access project included $300 million in site preparation. The Second Avenue Subway required $335 million in site preparation, which came to 11% of its total construction budget. Site preparation is particularly difficult in New York City, because of the preponderance of electrical wires and pipes that are underground. This process involves bargaining between the MTA and New York City's utilities; it is not clear whether the infrastructure sponsors are striking their best bargains. Barro (2019) writes that, "if the city or the state brought more of its utility-oversight powers to bear to hold down costs for the MTA, we might be able to take a bite out of this particular cost problem."

Beyond accounting, there are three deeper explanations for why infrastructure costs are so high in the United States. First, it is possible that conditions are more demanding and that raw materials and labor are more expensive than elsewhere. This explanation suggests that higher costs are unavoidable but should be considered in discussions of optimal infrastructure policy,

[8] Brooks and Liscow (2021) do not find that rising labor costs contribute substantially to the time series increase in construction costs between the 1960s and the 1980s. It may still be the case that labor costs in some large cities contribute to high infrastructure costs there.

since higher costs are a good reason to build less infrastructure. Second, it is possible that the agencies charged with building infrastructure are poorly designed to manage costs. In this case, there may be changes to infrastructure building practices that could lower costs and stretch infrastructure budgets. Third, it is possible that external factors, especially the threat of litigation or political backlash, lead to expensive forms of mitigation, which change the nature and cost of building projects (Altshuler and Luberoff 2005).

How can we assess these three competing explanations? Arguably, the conditions for tunneling in Manhattan are as difficult as anywhere in the world, although cost estimates for projects in London, which are all completely underground, are only one-third as high as those in New York City. Labor costs are higher in the United States than elsewhere, and especially so in New York City, but this reflects institutions as well as generally high labor costs. The Bureau of Labor Statistics (BLS) reports that in May 2020, the median hourly wage for electricians in the New York City metropolitan area was $36.13, and the mean was $40.48.[9] BVP (2018) report a minimum hourly wage for electricians of $65 on the East Side Access project and an added $62 dollars per hour in benefits, making the per-unit labor cost for the project a multiple of the prevailing wage.

Moving beyond labor costs, many of the capital goods that are used as inputs to highway construction, as well as most materials, possibly excepting some locally manufactured concrete, are bought and sold in regional or global markets. Even if the law of one price does not hold for these inputs, it is unlikely that deviations in prices across countries are large enough to be able to account for significant project cost differentials.

Procurement rules, which may achieve meritorious social goals, can also raise infrastructure costs. One study finds that allocations for minority contractors in California increase construction costs by 9% (Marion 2009). Such provisions also increase the number of Black-owned business, which highlights the cost-vs.-social goals trade-off (Chatterji, Chay, and Fairlie 2014). It is important to consider these trade-offs before embarking on a major infrastructure spending program.

While the extraordinary price tag of New York City projects reflects in part the challenges of building in an already hyper-dense locale, there is no equivalent explanation for the high costs of building highways in lower-density states (Brooks and Liscow 2021). Most of the United States is far less dense than most of Europe, and much of the country is reasonably flat. That turns the spotlight to labor costs. While labor costs may contribute to the high costs of highway work in the United States, the mean hourly wage in the industry labeled "Highway, Street, and Bridge Construction," is under $30 per hour according to the BLS.[10] The labor share for highway work, as opposed to tunneling in New York City, is less than 30% (Garin 2019). Even 30% higher wages in the United States would only lead to an increase of 9% in total costs. This arithmetic

[9] https://www.bls.gov/oes/current/oes_35620.htm
[10] https://www.bls.gov/oes/current/naics4_237300.htm

suggests that there is still much to be done in accounting for the higher infrastructure costs in the Unites States.

5.b. Infrastructure costs have risen over time

Between the late 1950s and the early 1990s, Brooks and Liscow (2021) estimate, overall highway construction costs in the United States increased fourfold. They also systematically evaluate the role that input costs and geographic difficulty played in increase the costs of highway construction. They find that the real cost of materials and labor barely changed, so input costs cannot account for the overall increase. To control for changing difficulty in the geography of construction, they measure the average population density, hilliness (slope), and contact with water of new road segments in a state during a given year. They also control for state fixed effects to capture changes in the location of new highway segments; these factors only explain about 6% of the overall increase in the cost of building. They conclude that the increasing cost of accommodating citizen's complaints about the downsides of new highways has been a central source of cost increase.

Brinkman and Lin (2019) discuss "freeway revolts" in which neighborhoods fought to stop nearby road construction. This activity exploded in the 1970s, which also saw a dramatic increase in the number of newspaper articles about the environmental damage associated with interstate highways. Brooks and Liscow (2019) document a dramatic increase in the number of "wiggles" in new roads over time. These increase costs but may allow highways to bypass sensitive areas. The number of ramps and bridges has also increased: these also reduce the need to bulldoze existing structures and increase costs.

These facts are compatible with the narrative arc of Altshuler and Luberoff (2003), who focus on megaprojects, rather than highways. They split the post-war experience into three periods. During the first period, large urban construction projects occurred with little opposition. Robert Moses' New York projects, such as the Cross Bronx Expressway, perhaps epitomize this epoch. In the second period, neighborhood activists, such as Jane Jacobs, borrowed organizing techniques from the civil rights movement and learned how to block infrastructure projects. In the third period, which began in the 1970s and continues to this day, the public sector responded to a more empowered citizenry by avoiding relocation and offering expensive mitigation for the local consequences of new projects. Massachusetts' Big Dig epitomizes this era.[11] Its price tag ballooned from $2.5 billion in 1985 to $14.8 billion in 2008, reflecting a combination of delays, modifications to construction plans, and design changes that were adopted in response to various public interest groups. The actual costs may have been as high as $18 billion (Bearfield and Dubnick 2009).

[11] Fred Salvucci, the Massachusetts transportation secretary who shepherded the Big Dig project, had a grandmother who was relocated by an earlier megaproject. He was determined to complete the project without any relocations and with minimal resident discomfort.

The cost overruns in the Big Dig reflected in part the perpetual problem that optimistic figures are used to sell large projects to the public, but there were also genuine surprises that raised the project's cost. Boston is an old city with a great deal of underground infrastructure, and replacing and relocating unexpected pipes, electrical, and sewer lines added to costs. Moreover, to offset the air pollution that would be associated with the increased vehicle traffic after completion of the Big Dig, the project needed to include funding for pollution mitigation efforts such as the restoration of previously inactive commuter rail lines. We are not aware of any cost-benefit analysis in the selection of these mitigation projects.

With mega-projects, and even with ordinary highway construction, it is hard to distinguish between the cost impact of mitigation, which presumably delivers some value to impacted communities, and the cost impact of procurement and managerial problems. These two factors can compound. Managing a project that involves building a simple straight highway is vastly easier than managing a tunnel project, but tunnels are one way of reducing the impact on neighborhoods. Public bureaucracies that were up to the task of building relatively simple projects during the first era may find managing costs far harder during the current era of more complex construction projects.

5.c. Making infrastructure more affordable

Procurement practices, which are largely set at the state and local level, are potentially important determinants of the cost of infrastructure projects. The rules that govern state departments of transportation, labor negotiation, and environmental impact reviews are typically determined by state law and state and city politics. The federal government has access to only blunt tools for modifying the infrastructure procurement process and reigning in costs.

5.c.1. Apply cost-benefit analysis

If either a national infrastructure bank or a cost-benefit rule becomes the new norm, then higher project costs will make it harder, for a given level of public benefits, for a project to receive funding. The benefits of new projects would need to be higher in states where costs are particularly high, which could bring pressure to trim costs. It could also lead to more systematic over-statement of benefits in such states, or under-estimation of costs in the project planning stage; both would need to be monitored carefully.

5.c.2. Purchase from low-cost suppliers

Relaxing "Buy American" provisions is another way in which the federal government could reduce the cost of new infrastructure projects. Horrox and Casale (2019) claim that the average cost of electric transit buses is $750,000 in the United States, reportedly double that paid by the U.K., which has laxer rules about buying British products. The cost of an electric bus in Asia is lower still. Yet procurement in the bus industry is hampered by national and local regulations (Li, Kahn, and Nickelsburg 2015). Higher costs associated with domestic content rules will make the U.S. conversion to electric buses slower and far more expensive than that conversion elsewhere. Tariffs can have the same effect in raising project costs. The cost of the transition to solar energy will be much higher if tariffs raise the cost of solar panels and related products. There are many arguments for domestic content rules and tariff protection, and it is important to consider alternative policies that could address the underlying policy goals with fewer distortions. For example, when such policies are justified on the grounds of domestic income redistribution, it may be possible to achieve a similar degree of redistribution by other means such as transfer programs without incurring the cost of distorting infrastructure purchase decisions and confounding other price signals.

5.c.3. Streamline environmental reviews

If the federal government were committed to more rapid project completion and fewer cost overruns, it could model streamlined environmental reviews for infrastructure projects. This could be done in the context of directly funded projects, such as those under the TIGER/BUILD program described in Congressional Research Service (2019). In the context of this program, the federal government could directly assess whether mitigation expenses are excessive. The federal government also imposes its own environmental impact review process, which can go beyond the environmental impact reviews mandated by the states. The discretionary DOT grants associated with this program represent a small fraction of total infrastructure funding, but they offer an opportunity to make a statement about best practices.[12]

One option would be for DOT to make a public commitment to ensure that the social costs of environmental regulations do not exceed their benefits. It could also commit to increase the speed of these reviews to eliminate the costs of delay. DOT analysts could work with TIGER grant recipients to ensure that mitigation efforts satisfy cost-benefit analysis. Such actions would have a symbolic and informational effect, suggesting to states that they should also be asking whether environmental impact reviews are too onerous or whether mitigation effects are excessive, and providing a model of how to do this.

States, which have primary control over transportation within the United States, are best positioned to reduce construction delays and mitigation-related costs. They control state-level environmental impact review processes, labor-related rules and the project choices that drive mitigation costs. Any reform must acknowledge that there often are environmental costs associated with infrastructure projects, and that cost-effective mitigation is appropriate. The key is to determine when benefits exceed costs, and to find ways to expedite project approval.

[12] This analysis assumes that the federal government could move more quickly than the states with regard to project approval. Given state-level heterogeneity, it is possible that some states are already moving quickly relative to what a federal program could deliver. For other states, however, the cost saving could be substantial.

5.c.4. Harmonize implementation of prevailing wage requirements

The Davis-Bacon Act requires workers on federally funded projects to be paid the prevailing wage, and cost-cutting advocates have long urged its reconsideration. Yet prevailing wages are interpreted quite differently in different locations. In New York City, the Comptroller determines the prevailing wage. For electricians, in 2021 that was $58 per hour, with a supplemental benefit requirement of $58.46. After seven hours in a day, overtime kicks in, causing the wage to increase to $82 per hour and the benefit rate to rise to $62 per hour.[13] While a complete analysis would require more detailed information on the nature of the work being performed and the necessary skill sets for the workers, the Comptroller's prevailing wage is significantly higher than the average wage as reported by the BLS for the New York metropolitan area ($36 per hour). By comparison, in Houston, the prevailing wage is listed as $31 per hour and the benefit level is $9 per hour. The BLS reports that the average wage for an electrician in Houston is $25.47 per hour, about three-quarters of the New York City figure from the BLS. The non-overtime prevailing wage plus benefit for New York City is nearly three times that in Houston, but the effective cost difference may be even larger. Texas follows the general rule that overtime begins after a 40-hour week, while New York City has occupation-specific overtime rules that kick in sooner. New York also requires a higher minimum wage for nonstandard shifts, which Texas does not.

Even within the Davis-Bacon framework, the federal government could send much stronger signals to states and localities about using BLS data to establish prevailing wages. Similarly, simplified rules about benefits and overtime could be promulgated either in statute or through DOT. States and localities are free to require higher than prevailing wages on their projects, but at least it should be clear that this is the choice of local officials, not an adherence to federal law.

5.c.5. Strengthen local procurement offices

Procedures followed by local procurement agencies represent the largest direct contributor to total project cost, and the one that is probably most difficult to control. BVP (2018) emphasize choices about procurement made by the MTA that added significantly to the cost of key projects. Two examples illustrate this. First, the MTA voluntarily follows the procedures in New York's Wicks Law, which means that "systems for electrical, HVAC, and communications are individual bids separate from civil construction tasks such as tunneling and station construction." Instead of contracting with a single entity that does all these highly connected tasks, or that bids the total project and subcontracts them, MTA entertains separate bids for each. This process proliferates contract delays and is likely to increase costs. Second, the MTA must accept the lowest bid, even if that bidder seems unlikely to be able to complete the job. Bosio et al. (2020) point out that such rules, put in place to reduce bribery in a more corrupt era, still hamper procurement agencies today.

[13] https://comptroller.nyc.gov/wp-content/uploads/documents/ConstructionWorkerSchedule-2020-2021.pdf

In many places, state and local government procurement rules are likely to raise the cost of infrastructure projects. Governments should quantify these costs, and assess whether the benefits of these rules justify their costs. Rigorous application of cost-benefit analysis would highlight the cost of these rules, because the higher prices for infrastructure projects associated with them might mean that the project is not funded.

6. Beyond building: making better use of infrastructure, new and old

Most of the standard complaints about infrastructure in the United States refer to poor maintenance and congestion, rather a lack of roads or bridges. The CBO (1988) reported a 75% rate of return for urban road maintenance, and a 16% rate for rural road maintenance. Transportation economists generally assign a high value to road maintenance. Failure to maintain infrastructure can raise the cost of using that infrastructure, for example by imposing wear-and-tear on vehicles using roads with potholes. It can also raise the risk of more catastrophic losses. This section discusses using infrastructure better. It focuses on four issues: raising the priority on maintenance of existing infrastructure rather than new construction, the potential role of user fees in funding maintenance and reducing congestion, the possibilities and shortcomings of public-private partnerships, and non-infrastructure investments that complement infrastructure projects.

6.a. Prioritizing maintenance of existing infrastructure

Spending on highways is currently almost evenly divided between new construction and maintenance of existing roads. The CBO (2018) reports that for highways, operations and maintenance represented 47% of total government spending in 2017. Maintenance accounts for a larger share of other major infrastructure categories: 72% for water utilities and water resources, 66% for mass transit and rail, and 69% for aviation.

At prevailing spending patterns, the return to maintaining existing roads is likely to exceed that of new construction (Gramlich 1994). While there are counter-examples to any general rule of this form, the direction of this argument is that maintenance should receive greater priority than it currently does. The rule for efficient allocation is familiar: maintenance should be prioritized until the point where the rates of return are the same for maintenance and new construction. Adopting a rate of return threshold for new projects would do this explicitly, and if maintenance were included in the project set, projects that involve new construction would explicitly compete with maintenance in resource allocation. New construction projects would only get approved if their rate of return exceeds the rate of return to maintenance.

Another approach is to require that all funds dispersed by the National Highway Trust Fund (NHTF) be used for road maintenance, as proposed by Kahn and Levinson (2011). They also suggest that new roads would be supported by a National Highway Bank, which would lend but not grant funds to states for new construction. A less radical plan would require that a minimum percent of all NHTF payments be used for maintenance and embed the National Highway Bank in a larger national infrastructure bank that both lends and grants funds. Each of these rule-of-thumb options represents a step toward requiring new projects to meet a rate of return threshold that is calibrated to the return on maintenance spending.

The NHTF-for-maintenance proposal is the most straightforward of these proposals to implement, although it may be the most difficult politically. The fixed-share option is also straightforward. Implementing a rate-of-return threshold is somewhat more challenging because it requires estimating an average rate of return for road maintenance in the state and evaluating rates of return for all new projects. This is a benefit, not a cost, since forcing the public sector to estimate rates of return is an important step on the path toward better infrastructure policy.

While highway maintenance is the largest category of infrastructure maintenance, maintenance for two other types of physical infrastructure, bridges and dams, is important for avoiding potential catastrophic failures. Bridge safety is also funded from the NHTF. Under the National Bridge Inspection Program, state Departments of Transportation are required to inspect bridges longer than 20 feet at least every two years, and to report data to the DOT. The spending rule that prioritizes maintenance could be modified to require repairing structurally deficient bridges before spending on any other maintenance projects, perhaps with an opt-out mechanism allowing a state to petition DOT for a waiver if a structurally deficient bridge is not unsafe in any way.

Dam monitoring is currently more haphazard than bridge safety monitoring. Three separate federal agencies are involved, including the Federal Emergency Management Agency (FEMA), which provides grants and training, the Federal Energy Regulatory Commission (FERC), which inspects hydroelectric dams, and the U.S. Army Corps of Engineers, which maintains the National Inventory of Dams. An alternative to the status quo would be to create a single dam inspection agency, charged with regularly monitoring all significant dams in the United States. If a dam is deemed to enter into a danger zone, then its owners must remedy the issue within a fixed amount of time. The FERC inspection process already follows this structure.

6.b. Expanding the role of user charges and congestion fees

The Highway Trust Fund charges road users by levying a gasoline tax, and then it deploys those user fees to fund roads and road maintenance. Requiring users to pay for their infrastructure limits overuse and generates revenues. One can argue that the United States should build more infrastructure, and better maintain the infrastructure that it has, without believing that the federal government should pay for any of it. Levying a user charge on roads would not only help to fund these roads, but it would also offset the subsidy to carbon intensive driving that comes from federally funded roads.

The first case for user fee financing is that the size of the fee can be tied to the depreciation costs associated with infrastructure use. A U.S. Government Accountability Office study (1979) found that one five-axle tractor-trailer did as much road damage as 9,600 cars. Pais, Amorim, and Minhoto (2003) corroborate the estimates of the damage associated with heavy vehicles. A basic principle of public economics is that efficient outcomes occur when individuals pay for the social costs of their actions. Driving, and especially driving trucks, causes road damage; efficiency requires that drivers pay for those costs. The absence of such user charges implicitly encourages heavy trucks that create disproportional damage on roads. Winston (2013) reports that the absence of payment-damage charges for heavy trucks imposes an annual welfare loss of $15 billion ($2021).

Congestion presents a second argument for charging drivers more to use the roads. Starting with Singapore in 1975, congestion pricing has been adopted in a number of major cities, including London and Stockholm. At its best, congestion pricing can change by street and time of day and provide real-time incentives to reduce driving and make streets more fluid. At this point, congestion pricing can be implemented with sophisticated GPS monitoring systems that impose no time costs on drivers. Winston (2013) estimates that the absence of congestion pricing imposes a welfare cost of $62 billion per year ($2021) on households. This value is likely to be an underestimate of the total cost of congestion, since it excludes the cost of delays for shippers.

Politically, there is rarely support for raising gas taxes or imposing congestion fees. The debate over the American Jobs Plan illustrates this, since even though the federal gasoline excise tax has not been increased since 1993, there has been strong resistance to raising it. Part, but not all, of the objection stems from concerns about the distributional burden of such a tax increase. Voters appear to be more accepting of tolls on new roads than of new charges on existing roads that used to be free. One implication of that is that new infrastructure should be tolled immediately to eliminate a precedent for free use. One way to adopt congestion charges would be to apply them initially to autonomous vehicles; over time the charge could be extended to vehicles with drivers.

Opponents of user fees argue that they are regressive, but higher income households use many forms of infrastructure more than the poor and would consequently pay more of the user fees associated with them. A 2017 survey of air travel found that the average person living in a household with income of less than $25,000 made one airline trip per year, compared with 5.4 trips for the average person in a household with income of $150,000 or greater (Heimlich and Jackson 2018). A survey commissioned by the Connecticut Department of Transportation (2018) found that nearly 50% of the rail trips in the state were taken by individuals from households with income of more than $150,000, while less than 5% of rail travelers had household income of less than $50,000. In contrast, the Connecticut survey found just the opposite for local bus trips: Nearly 50% of riders had household income of less than $25,000. This suggests that there is a stronger case, on distributional grounds, for subsidizing bus service than train or airport use.

The distributional impact of highway charges and of taxes on gasoline and diesel fuel has been an important concern when higher taxes are proposed (Kile 2021). Gasoline is a significant budget item for many low-income households, and gasoline purchases as a share of household annual income are higher for low-income than higher-income households (Chernick and Reschovsky 1997), although Poterba (1991) points out that the ratio of all consumption to income is much higher at low than at high incomes, and that the share of consumption spending devoted to gasoline is lower at low incomes than middle incomes. Some estimates suggest that the long-run elasticity of fuel demand with respect to income is over one (Graham and Glaister 2004), meaning that fuel purchases relative to income rise with income, but other research suggests that the vehicle miles driven rise less rapidly than income (Small and Van Dender 2007). There are also issues of geographic distribution when taxing gasoline, since average gasoline purchases vary substantially across location; they are higher in rural than urban areas. A key question is whether the distributional impact of a higher gasoline tax, or of a related user fee such as a vehicle miles traveled tax, could be offset by other policies, such as a targeted income tax provision or a SNAP-like program to reduce the cost of fuel purchases for low-income households.

For some types of infrastructure, the marginal cost of use is lower than the average cost of provision. Achieving economic efficiency in such cases requires charging the marginal cost of use and making up the difference with revenue from another source. Hong Kong Mass Transit Railway's (MTR) value capture program provides an excellent example of such cross-subsidization. MTR is both a transit company and a real estate company that erects tall buildings above or near their subway stops. The returns from the real estate development help to cover the revenue shortfall associated with the low fares.

Historically, a commitment to user fee financing has been helpful in securing low interest rate loans for entities like Robert Moses' Triborough Bridge Authority. Low interest rates today make debt-financed infrastructure investment more appealing because of the low cost of capital. If the debt was taken on by a special authority with the right to charge tolls, then the infrastructure could be financed with little impact on current budgets. That structure essentially replicates, inside governing, the financial model of public-private partnerships.

6.c. What role for public-private partnerships?

Discussions of new infrastructure programs often include the possibility of public-private partnerships as a means of providing financial support beyond that available from the public sector, or as a way of managing the projects to address issues such as service quality and maintenance. public-private partnerships can be a way of solving some problems that may confront the public sector in the construction or operation of infrastructure. They are not, however, well suited to all infrastructure projects, and they should only be used when it is clear what problem they are designed to solve, and how they will solve it. In some cases, when the answers to these questions are not clear and public-private partnerships are adopted to relax fiscal constraints on the public sector, they can actually raise the long-run cost of infrastructure provision.

Engel, Fischer, and Galetovic (2014) argue that the better alignment of operational incentives in private rather than public projects is a benefit, and possibly the most important benefit, of public-private partnerships. Transferring responsibility for maintenance out of the public sector and making the owner of the project dependent on user fee revenue can improve incentives for operations. When a private owner's return is a function of the future stream of user fees, there is an incentive for the infrastructure operator to keep quality high so that the user base is large and the revenue stream stays high. In contrast, the incentives to preserve the user base may be weaker for public sector entities that can rely on general tax dollars.

A recent illustration of the construction differences between public and private owners comes from India. Singh (2018) compares the roughness of public and private roads in India, exploiting the fact that on some highways, the road will alternative between publicly owned and privately owned segments. He measures road roughness using vertical acceleration measures and finds striking differences in road roughness by ownership structure: public roads are rougher. He argues that this difference reflects the fact that private providers anticipate having to pay for their own maintenance, which means that they ensure that initial road quality is high. Public roads are built by private contractors who have no stake in road maintenance or in road usage, and consequently they build roads that are not durable.

Private highways have a long history in the United States. The Philadelphia and Lancaster Turnpike, which opened in 1795, was the first long-distance, gravel road in America. It was also privately owned. Long-distance canals required so much investment that they were typically public in the United States. The Erie Canal, financed by the State of New York, was a tremendous success. The Potomac Company, a private enterprise led by George Washington before he became president, was not. Railroad companies were initially private, although they did receive subsidies, typically in the form of land grants. The current view that transportation infrastructure is naturally public reflects the particular experience of the 20th century, during which passenger rail moved from private to public hands, and highways were built by governments.

Toll roads are plausible candidates for privatization in many settings, although the global track record with private roads includes many very poor outcomes (Engel, Fischer, and Galetovic 2014). In the United States, a private consortium operated the Indiana Toll Road for eight years beginning in 2006, but it filed for bankruptcy in 2014. The I-91 Express Lanes in California are one of the few examples of successful private highways in the United States. They run within the median of the Riverside Freeway which courses through Riverside and Orange Counties. The highway costs change with the time of day, and the peak price to travel the full 18 miles is over $20. Although this may well be the appropriate congestion charge and obviously plenty of customers are willing to pay that price, it is hard to imagine a government entity having the courage to charge drivers over one dollar per mile for access to a road.

Private roads are far less common in the United States than in the European Union; so are private airports. The Federal Aviation Administration began a pilot privatization program in 1997. While 12 airports applied, only one—Hendry Airport in the Everglades—is currently approved, and only one airport ever operated in the program —Stewart Airport in Newburgh, New York from 2000 to 2007.[14] The Branson Airport in Missouri was also built and operated by a private company with public support. In contrast, a large number of European and Asian airports, including Heathrow and Rome Airport, are operated by private companies, which are often partially owned by the government. Oum, Adler, and Yu (2009) look at privatization globally and find that "airports with government majority ownership and those owned by multi-levels of government are significantly less efficient than airports with a private majority ownership," corroborating the casual experience that many travelers have in public U.S. and private European airports. They also note that "airports with a private majority ownership derive a much higher proportion (56%) of their total revenue from non-aviation services." The fact that E.U. and U.K. airports can often feel like shopping malls illustrates the nature of those non-aviation services.

Even if privatized airports were no better at airport operations than their public sector counterparts, they do seem to be more entrepreneurial in the complementary task of selling goods and services to flyers. The revenue associated with such enterprises can help to fill the gap between the average cost of infrastructure use and the charges levied on users. The example of Hong Kong's MTR, which as noted above builds real estate that is connected with its rail service, suggests that this is a more general point. Private companies have the ability to more readily branch into different and relative businesses. Public entities that are focused on infrastructure just focus on infrastructure, perhaps because of the restrictions that the public sector places on the scope of departments and agencies.

In some cases, privatization is primarily a financial transaction, designed to raise near-term revenue for a state or local government. The case of Chicago's sale of future revenues from parking meters to a private entity, which generated near-term revenue but reduced the city's long-term income, illustrates the challenges of privatization. Private firms will pay public entities up front for a stream of future revenues. In some cases, a lack of experience on the part of the public sector enables the private purchasers to underpay. In reviewing the sale of future parking meter revenue to a private firm, the Chicago Inspector General found that "the City was paid, conservatively, $974 million less for this 75-year lease than the City would have received from 75 years of parking-meter revenue had it retained the parking-meter system under the same terms that the City agreed to in the lease."[15]

The Inspector General's evaluation assumed a discount factor for the city of 5 to 5.5%, which is far lower than the private discount factor used to evaluate the stream of earnings (Hoffman 2009). Is this reasonable? Long-lived governments should be more patient than most private

[14] https://www.faa.gov/airports/airport_compliance/privatization/
[15] https://igchicago.org/wp-content/uploads/2011/03/Parking-Meter-Report.pdf

companies, and if they are, there is no long-run benefit to the public sector from transferring a flow of future revenues to a private entity unless there is some major gain in efficiency. Similarly, large public entities are typically better able to bear risks than most private firms, which suggests that private entities may also apply a greater risk premium in evaluating future revenue streams. This should reduce the value that a private sector bidder, relative to a public sector entity, would place on the revenue stream.

The financial case for public-private partnerships depends on their being able to borrow at better rates than a city government or to bear risk better. Yet even if governments, like the state of Illinois, are themselves seen as a credit risk, they can still set up special purpose, independent entities that will receive the dedicated flow of funds from the infrastructure project. Under Robert Moses, New York's Triborough Bridge Authority was regularly seen as a better risk by bond markets than New York City itself. The use of public-private partnerships to front-load revenue is often a sign of a failure in public sector decision-making.

Public-private partnerships make most sense when they can reduce costs, bring specialized expertise, or improve quality. We discussed previously the many constraints that bind the Metropolitan Transit Authority and increase the price of construction. While it might be better to reduce the constraints, a public-private partnership conceivably offers the possibility of bypassing them altogether. In some states, private providers cannot avoid the rules that bind public behavior. In Massachusetts, for example, the Pacheco laws require that privatization must not only save money given current public practices but also that privatization would save money even if state employees work in the "most cost-efficient manner" and the private provider pays workers no less than their public sector equivalents.

One factor that may distinguish public and private entities is their capacity to levy fees and increase prices for infrastructure access. Once a private firm is charged with managing a project, it may face less political heat from proposed increases in user fees; this may make it easier for a privately managed infrastructure project to achieve efficient utilization.

6.d. Complementary investments and activities

There is a fundamental complementarity between transportation infrastructure and real estate development. Building infrastructure that increases access to workplaces and entertainment venues will cause the demand for space nearby to increase, generating a windfall to current property owners and an opportunity to deliver even more value by building at greater density levels. This fact lies behind the strategy pursued by Hong Kong's MTR, which offers an ingenious way of capturing rents created by infrastructure projects, but it is hard to imagine any large public transportation–related entity in the United States acting like a commercial developer.[16]

This motivates the movement toward tax increment financing and land value capture. The basic idea of both is to funnel some part of the increase in land values created by infrastructure projects back to pay for these projects. While attractive in principle, actually determining the impact of new roads on land values can be quite difficult in practice and would likely be subject to political gaming.

Tax increment financing is just about paying for infrastructure. Up-zoning areas near new infrastructure is a means of delivering greater overall social benefits from transportation infrastructure. If a new train station is built in an area, but density cannot be added to that area, then the benefits of the train will be minimal. A reasonable requirement is that areas that benefit from new infrastructure investment make it much easier to build homes nearby.

There are other services beyond real estate that can complement transportation, as the case of retail in commercial airports illustrates. For example, busses and trains have long featured advertisements within their vehicles. Trains also sell food. Such services can provide revenues and also improve the transportation experience for users. These are activities at which private entities are likely to have comparative advantage relative to public transit authorities.

In contrast, rural broadband is an area where the public sector is much better poised than the private sector to provide complementary services, such as education. Online education during the COVID-19 pandemic required broadband, a good student computer, and students and teachers who were comfortable with remote learning. Preparing students for continued remote learning in addition to traditional in-person learning will require public investments, especially in training, to ensure that broadband is fully utilized.

In principle, it is possible to have a private company providing a massively subsidized product, whether it is water for poor urbanites in 1880 or broadband for poor residents of rural states today, but private lobbyists are good at making the case for ever larger subsidies. If higher costs enable the company to make the case for larger subsidies, then there are few incentives for limiting expense. Voucher programs are a natural tool for subsidizing consumption, but they are a bad fit for situations where there is a single monopoly provider of either broadband or water.

[16] BVP (2018) point out that in the Second Avenue Subway project, "the MTA chose to forego development on six corner lots, building only vents and entrances instead of a larger building that could have combined residential and commercial uses with transit." Only three of those lots were good prospects for development, but estimates place their market value around $125 million in 2015. Unlike Hong Kong's MTR, the MTA sees itself as a transit authority, not as a real estate developer, and the MTA's staff are not particularly trained in real estate development.

7. The political challenges facing infrastructure investment

Building infrastructure is largely an engineering problem, but many of the factors that contribute to the poor performance of infrastructure in the United States do not involve engineering. New projects are built and maintenance is neglected. Small groups of empowered citizens can delay or block valuable projects. Public sector unions impose work rules that raise costs and delay schedules. These factors all stem from politics. Politicians like new projects because they get noticed. The media will applaud a new bridge or highway, and while an occasional media story may highlight potholes, repaving a road is unlikely to be a newsworthy event.

The approval process for infrastructure projects involves critical local review and inputs. Neighborhood activists exert sway because new infrastructure really does create tangible and significant costs to them. Consequently, they bother to fight, and they attract attention from politicians and administrators. At the same time, the dispersed thousands or millions who will benefit a small amount from the project pay far less attention. The taxpayers who ultimately cover the added cost of abatement are even less attentive (Glaeser and Ponzetto 2018). Small interest groups are often more effective than dispersed alliances with weak incentives, as Olson (1965) argued decades ago. Some small citizen groups may extract costly project design modifications that raise the price tag for new infrastructure projects, even though the ultimate social benefits may be modest. At the same time, infrastructure projects that might benefit some less well-organized groups may never be built, because of the lack of experience in making the political case for such projects.

The problem of getting to yes becomes even harder when infrastructure spans multiple jurisdictions. Straightening out passenger rail between Boston and New York is practically unthinkable as long as that rail goes through Connecticut, which has little interest in speeding the journey. Anything that spans multiple stakes typically needs federal engagement.

There are several federal actions that might address some of these issues, such as reserving some portion of the Highway Trust Fund for road maintenance. That structure essentially fights against the political urge to favor new projects. However, many of these problems cannot ultimately be solved by the federal government alone. It does not have the power to change local politics, pass state laws relating the environment, or change the procurement process for state agencies. State governments do have that power. Consequently, reducing costs requires the federal government to interact with the states and to make reform a precondition for funding.

It is hard to imagine how that can happen for any standard pass-through program, like the trust fund. For the federal government to meaningfully impact state behavior, it will need to bargain with the states on a project-by-project basis. That cannot be done by the national legislature and it cannot really be done by any entity that is directly political. An effective organization would need independent authority to craft deals that would lower costs and increase value. It would need to be well staffed and well funded. A national infrastructure bank might play such a role, but it is an untried idea and unlikely to remedy all of the difficult issues. We recognize the potential downsides of such a bank, but given the challenges of reducing infrastructure costs and improving infrastructure administration otherwise, the concept deserves serious consideration.

8. Conclusion

Our assessment of the role of economic analysis in infrastructure investment suggests several broad conclusions.

First, it is difficult to place high confidence in widely discussed measures of infrastructure "need." The most reliable way to develop such estimates would be by applying cost-benefit analysis on a project-by-project basis and aggregating the results. But that approach is expensive, given the vast array of potential infrastructure projects, and it is subject to gaming by overstating future benefits and low-balling costs. Estimates of the returns to maintaining existing infrastructure are often higher than estimates of the returns to undertaking new projects, which suggests the importance of guarding against "ribbon-cutting bias" toward new initiatives on the part of both elected leaders and the heads of government agencies. Any major infrastructure initiative should emphasize careful *ex ante* analysis of project costs and benefits, with oversight where feasible of padding by advocates of the assumptions regarding future costs and benefits.

Second, infrastructure projects in the United States are expensive relative to those in other nations. The precise reasons are difficult to identify, but they include project designs that incorporate many features that remediate adverse project effects, such as highway noise and the inconvenience of disruption while building, required wages for workers that may exceed area norms, project delay through regulatory processes, and weak procurement and project management by the relevant government agencies.

Third, user fees warrant greater consideration as a source of infrastructure project financing. Such fees, along with congestion charges, can improve the efficiency of infrastructure use. While there are concerns about the distributional effects of user fees and burdens on low-income groups in particular, the pattern of infrastructure use across income groups suggest that some user fees are progressive—higher income households use airports, for example, more than their lower-income counterparts. Public transit, particularly buses, is a notable exception. Rather than carry out income redistribution by exempting infrastructure use from charges, policymakers could consider targeted redistribution programs, such as transit vouchers for low-income households or infrastructure-use rebates mediated through the tax system. Some states currently provide income tax relief for renters or for commuters who can document their travel costs.

Finally, public-private partnerships can provide a means to increase operational efficiency, but arguments that they allow project sponsors to access low-cost capital should be viewed with caution. In some cases, the cost of capital for private entities may exceed that for public sector borrowers and relying on private finance rather than public funding may ultimately increase the cost of the project. Some state and local governments may be attracted to these partnerships because they relieve current cash flow constraints, but they may come at a price in terms of the long-term cost of infrastructure services.

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