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Cost overruns in infrastructure projects: Evidence and implications

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Abstract. In recent years, there has been a sharp growth in both the magnitude and frequency of major infrastructure investments worldwide. Despite this boom in infrastructure spending, major projects continue to systematically underperform, as demonstrated in numerous empirical studies. In this paper, the author will discuss the factors underlying this growth in public spending, evaluate the empirical evidence on project cost overruns, and discuss the broader macroeconomic implications of this phenomenon.
Keywords. Macroeconomic implications, Major infrastructure investments, Growth.
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1. Introduction

Across the political spectrum, politicians have advocated for sprawling infrastructure spending plans, citing millions of purportedly "shovel-ready" jobs and positive impacts on economic growth. This phenomenon is a global one, as evident in the growth in the magnitude and frequency of government megaprojects over the last several decades. Far from driving meaningful economic growth, these schemes systematically underperform, undermining project viability in many instances.

Government projects are rarely evaluated on a comprehensive cost-benefit analysis basis; *ex-ante* evaluations are distorted by bureaucratic incentives, resulting in systematic cost and schedule overruns across project types and geographies. Comprehensive *ex-post* cost benefit analysis over an extended period after initial financing is not common practice among government agencies, although there are several prominent academic studies that have conducted such analyses. While benefits provided by public works are often difficult to directly ascertain, as network and spillover effects are frequently given arbitrary or inflated valuations, the costs side of the equation is the source of rampant waste and inefficiency by project promoters. The rule of thumb known as the "bureaucratic rule of 2" aptly describes the current state of government project management: to roughly determine the cost of a government

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provision, simply find the equivalent cost in the private sector and double it.

In the aftermath of the Global Financial Crisis of 2007-2008, there has emerged a commonly held notion that countercyclical monetary policy has run out of ammunition with interest rates at or near the zero lower bound, which has driven policy-makers to pursue heightened fiscal spending. This new paradigm has given rise to so-called Monetary Theory (MMT), a doctrine embraced by many figures on the progressive left. The theory states that fiscal deficits are irrelevant, given the assumption that governments can borrow in their own currencies and effectively keep inflation in check. Moreover, it serves as a justification for more government spending. Another implication of MMT is that fiscal policy should serve as the primary macroeconomic policy lever, rather than monetary policy. Proponents of this view fail to consider the fact that while economic dynamics have changed, monetary policy has not been rendered impotent. In fact, monetary policy "invariably dominates" when monetary and fiscal policies act in opposite directions (Greenwood, 2019). Rather than interest rates, the key element of monetary policy is maintaining the level of broad money in the economy.

As governments spend increasingly large amounts of money on increasingly large-scale projects, infrastructure has become a major flash point when it comes to questions of public spending. The below discussion focuses on the costs side of cost-benefit analysis and assesses the prevalence and implications of pervasive cost overruns across various government projects, both in the United States and worldwide.

2. Cost overruns in the United States

2.1. Historical project performance

Cost overruns have pervaded the federal government for centuries. According to a study conducted by economists Stanley Engerman and Kenneth Sokoloff, the vast majority of infrastructure projects throughout US history have had substantial cost overruns (Edwards & Kaeding, 2015). A notable example is the construction of the Erie Canal between 1817 and 1825; the initial construction went 46% over budget, and the canal's subsequent expansion went 142% over budget. Also, the Panama Canal's construction between 1902 to 1913 went 106% over budget. More recently, the cost to develop the "Healthcare.gov" website launched in 2013 ballooned from $464 million to $824 million (Edwards & Kaeding, 2015).

Private sector investments are governed by a system of profit and loss, as illustrated by Ludwig von Mises:

"In the capitalist system of society's economic organization, the entrepreneurs determine the course of production. In the performance of this function they are unconditionally and totally subject to the sovereignty of the buying public, the consumers. If they fail to produce in the cheapest and best possible way those commodities which the consumers are asking for most urgently, they suffer losses and are finally eliminated from their entrepreneurial position." (Mises, 1951).

Government decisions are instead implemented largely on the basis of political and bureaucratic interests and heavily skewed projections of costs and benefits. Historically, public investments in the US have primarily relied on such *ex-ante* benefit-cost analyses, which are especially handicapped in the absence of a comprehensive *ex-post* review of the actual economic performance of such projects – a requirement in the private sector to ensure profitability and efficiency.

In 1972, economist Robert Haveman conducted one of the first systematic efforts to assess actual government project performance. Haveman undertook an "exploratory effort" to determine how *ex-post* analysis can better inform and shape *ex-ante* forecasts for public projects, using various water resource investments as case studies. In what he characterizes as a "pilot study," Haveman deals with numerous aspects of the planning process for water resource investments (Haveman, 1972).

Haveman's study was unique in that it examined realized project benefits, in addition to costs. Major topics of study include *ex-post* evaluations of flood control projects, navigation facilities investments, hydroelectric projects, and cost estimation experience. In conclusion, Haveman found that standard *ex-ante* estimations of project benefits are seriously flawedacross the board. In an *ex-post* investigation of one flood control project, Haveman found that realized economic benefits considerably fell short of official estimates cited in the Corps of Engineers' *ex-ante* project report. Additionally, the chapters addressing navigation improvements challenge various *ex-ante* procedures for appraising projected benefits, concluding upon revaluation that per unit benefits were initially inflated. Haveman found that benefits were significantly overstated in his evaluation of hydroelectric projects as well, citing major shortfalls in the *ex-ante* review, including a failure to incorporate factors, such as changing technology, in the analysis of least-cost alternatives. On the cost side of the equation, Haveman' s*ex-post* assessment of 86 Corps of Engineers projects examined cost estimation performance and found considerable variance between estimates and actual costs. While the study was relatively small in scope, Haveman's work provided an important first step in project evaluation literature and highlighted the importance of comprehensive *ex-post* analyses.

In a 1973 study, economist Leonard Merewitz examined past cost overrun experiences and also concluded that large public works projects, over the last two centuries, have had a history of enormous cost overruns, and this phenomenon has been observed repeatedly in subsequent analyses (Merewitz, 1973). Merewitz found that costs for larger projects are more difficult to manage than smaller projects. Also, the longer a project continues, the greater the likelihood of cost overruns. Even after adjusting for inflation and changes to project scope throughout the planning process, delays and cost escalation tend to go hand in hand (Merewitz, 1973). Cost overruns are particularly problematic when projects' benefit-cost analysis and decision making processes were predicated on a cost estimate that was later determined to be inaccurate.

While certain exogenous causes of cost overrun, including unexpected inflation, technological problems, and unforeseen changes to project scope, are uncontrollable, poor administration is an important driving factor. Engineering, financial, and legal concerns can often be anticipated and appropriately factored into estimates. But, overly complex organizational structures, poor contracting practices, unnecessary changes to project scope, and inexperienced personnel can compound difficulties in project management and cost estimating (Merewitz, 1973).

Merewitz reviewed cost performance across project types to discern patterns of cost overruns. As shown in Table 1, Merewitz observed that cost overruns are most seriously underestimated in *ad hoc* public works projects, followed by building, and likely rapid transit projects.

Table 1. *Summary of Cost Estimation Experience – Merewitz (1973)*

Type of project	Number of projects	Mean ratio=Actual/Estimate
Water resource	49	1.39
Highway	49	1.26
Building	59	1.63
Rapid Transit	8	1.51
Ad Hoc	15	2.11
Total	180	1.50

Source: Merewitz, L. (1972). Prepared by Alexandria Edwards, the Johns Hopkins University.

Time and time again, cost overruns are standard across government projects. Major areas of federal waste include defense, energy, and transport projects, which are discussed in further detail below.

2.2. Transportation

A pattern of cost overruns in publicly funded transportation projects dates back centuries. While proponents of government spending often point to the aforementioned Erie Canal as a success, the project spurred the development of a "slew of government boondoggles," as state governments rushed to spend excessively on their own canal schemes, often overestimating demand and underestimating costs (Merewitz, 1973). Furthermore, routes were largely determined on the basis of political interests rather than economic benefits, resulting in large taxpayer losses. Today's urban rail schemes are analogous and constitute a major component of government infrastructure spending, and they are frequently subject to cost overruns and inflated ridership projections. In a 1990 report by the Department of Transportation, nine of the ten projects examined had cost overruns, with an average overrun of 50 percent (Pickrell, 1990). This trend has been replicated in numerous other studies and appears to be an international phenomenon.

A notable example is Boston's Central Artery tunnel, commonly known as the "Big Dig," which incurred over $12 billion in cost overrun and was constructed over a period of 25 years, from 1982 through 2007.[2]Table 2 provides a sampling of major American transportation infrastructure projects and associated cost overruns.

Table 2. *Sampling of transportation cost overruns*

Transportation	Projects Cost Estimate and Date of Estimate		
	Original	Recent or Final	Cost Overrun
Boston Big Dig	$2.6b (1985)	$14.6b (2005)	$12b
New York City East Side Access	$4.3b (1999)	$10.8b (2014)	$6.5b
San Francisco-Oakland Bay Bridge	$1.4b (1996)	$6.3b (2013)	$4.9b
Denver International Airport	$1.7b (1989)	$4.8b (1995)	$3.1b
New York City WTC Rail Station	$2.0b (2004)	$4.0b (2015)	$2.0b
Denver West Light Rail	$250m (1997)	$707m (2013)	$457m
Virginia Springfield interchange	$241m (1994)	$676m (2003)	$435m

Source: Edwards, & Kaeding, (2015). Prepared by Alexandria Edwards, the Johns Hopkins University.

2.3. Defense

The Department of Defense (DoD) is widely known forits history ofcost overruns on procurements of weapons and equipment. Former Comptroller General David Walker has characterized the Pentagon as having "a long-standing track record of over-promising and under-delivering with virtual impunity." (Pickrell, 1990). Numerous reports conducted by the Government Accountability Office (GAO) have found consistent cost escalations, and a 2014 GAO report stated that "weapon systems acquisition has been on GAO's high risk list since 1990."

The GAO monitors estimated costs of major weapons programs and has found that typical cost overrun percentage has not fallen over time; of the 91 programs examined in 2005, R&D costs were 33 percent overbudget, on average, and procurement costs were 18 percent overbudget. Additionally, for the 78 programs examined in 2014, R&D costs were 53 percent overbudget, on average, and procurement costs were 46 percent overbudget (Pickrell, 1990).

Moreover, the GAO has also noted that while private companies account for investment spending as a cost to be controlled, in the DoD, "new products in the form of budget line items can represent revenue. An agency may be able to justify a larger budget if it can win approval for more programs. Thus, weapon system programs can be viewed both as expenditures and revenue generators." (Pickrell, 1990).

Table 3 presents several defense projects and associated cost overruns:

Table 3. *Sampling of defense cost overruns*

Defense Projects	Per-Unit Cost Estimate and Date of Estimate		
	Original	Recent/Final	Cost Overrun
Littoral Combat Ship	$360m (2004)	$667m (2014)	$307m
Evolved Expendable Launch Vehicle	$102m (1998)	$376m (2013)	$274m
Joint Strike Fighter (F-35)	$79m (2001)	$138m (2013)	$59m
JPALS Landing System	$29m (2008)	$77m (2014)	$48m
G/ATOR Radar	$24m (2005)	$61m (2014)	$37m

Source: Edwards, & Kaeding, (2015). Prepared by Alexandria Edwards, the Johns Hopkins University.

2.4. Energy

Since the founding of the Department of Energy, its projects have experienced significant cost overruns. The largest part of the agency's budget is allocated to the National Nuclear Security Administration (NNSA), which manages the security of America's nuclear stockpile. The NNSA has been rife with cost overruns – in the case of the Mixed Oxide Fuel Fabrication Facility in South Carolina, costs skyrocketed from initial 2002 estimates of $1 billion to $7.8 billion, more than a 7-fold increase (Pickrell, 1990).

Environmental cleanup is the second largest component of the DOE's budget, widely known as "the legacy of waste created by federal nuclear weapons sites in the decades following World War II" and reformed only after a series of damaging reports during the 1980s (Pickrell, 1990). Taxpayers have funded over $150 billion to clean up the government's nuclear messes since 1990, yet the GAO found that the DOE's attempts to treat and dispose of waste has been plagued with false starts and failures, resulting in steadily growing estimates of the program's total cost." (Pickrell, 1990). According to a 2008 report, the GAO found that nine out of 10 cleanup projects resulted in cost escalations and schedule delays, ranging from overruns of $139 million to over $9 billion and delays of two to 15 years.

This pattern of cost overruns, schedule delays, and project mismanagement is evident in examples under administrations across the political spectrum. Table 4 includes examples of major energy projects and their respective costs:

Table 4. *Sampling of energy cost overruns*

Energy Projects	Cost Estimate and Date of Estimate		
	Original	Recent/Final	Cost Overrun
Hanford nuclear waste site	$4.3b (2000)	$13.4b (2012)	$9.1b
Superconducting Supercollider	$4.4b (1987)	$11.8b (1993)	$7.4b
NNSA-Savannah River	$1.0b (2002)	$7.8b (2014)	$6.8b
National Ignition Facility	$2.1b (1995)	$5.3b (2014)	$3.2b
Clinch River Breeder Reactor	$400m (1971)	$4.0b (1983)	$3.6b
FutureGen clean coal project	$950m (2003)	$1.8b (2008)	$850m

Source: Edwards, & Kaeding, (2015). Prepared by Alexandria Edwards, the Johns Hopkins University.

3. Literature review: Megaprojects & cost overruns as a global phenomenon

3.1. The "Megaproject paradox"

This pattern of pervasive cost overruns and mismanagement is evident in projects worldwide. Globally, countries are faced with "a new political and physical animal: the multibillion-dollar mega infrastructure project." (Flyvbjerg, 2003). The growth of megaprojects has amplified the impacts of pervasive cost overruns. The term megaproject generally refers to complex ventures that cost $1 billion or more, take many years to develop, involve multiple stakeholders, and impact millions of people (McKinsey Global Institute. [Retrieved from]). These multibillion dollar projects largely operate by an "iron law" – over budget, over time, over and over again. Oxford economist Bent Flyvbjerg is the world's most cited scholar in the field of megaproject planning and management, and his work focuses on deceptive and inaccurate cost estimations in infrastructure project planning. He has written extensively about such "Machiavellian projects," using project-level data to support the notion of systematic bias toward projects with cost overruns and benefit shortfalls in project planning.

Megaprojects are not only growing in size, but they are also being built in far greater numbers than ever before. Despite the apparent attractiveness of megaprojects, many of them have strikingly poor performance. Policymakers often fail to consider many factors, including the inherent riskiness, planning biases, and inaccuracies in cost, schedule, and benefit estimations. Table 5 illustrates the dismal history of cost overrun in large scale projects.

Table 5. *Large-scale projects have a calamitous history of cost overrun*

Project	Cost Overrun (%)
Suez Canal, Egypt	1,900
Scottish Parliament Building, Scotland	1,600
Sydney Opera House, Australia	1,400
Montreal Summer Olympics, Canada	1,300
Concorde supersonic airplane, UK, France	1,100
Troy and Greenfield railroad, USA	900
Excalibur Smart Projectile, USA, Sweden	650
Canadian Firearms Registry, Canada	590
Lake Placid Winter Olympics, USA	560
Medicare transaction system, USA	560
National Health Service IT system, UK	550
Bank of Norway headquarters, Norway	440
Furka base tunnel, Switzerland	300
Verrazano Narrows Bridge, USA	280
Boston's Big Dig artery/tunnel project, USA	220
Denver international airport, USA	200
Panama Canal, Panama	200
Minneapolis Hiawatha light rail line, USA	190
Humber bridge, UK	180
Dublin Port tunnel, Ireland	160
Montreal metro Laval extension, Canada	160
Copenhagen metro, Denmark	150
Boston-New York-Washington railway, USA	130
Great Belt rail tunnel, Denmark	120

London Limehouse road tunnel, UK	110
Brooklyn bridge, USA	100
ShinkansenJoetsu high-speed rail line, Japan	100
Channel tunnel, UK, France	80
Karlsruhe-Bretten light rail, Germany	80
London Jubilee line extension, UK	80
Bangkok metro, Thailand	70
Mexico City Metroline, Mexico	60
High-speed Rail Line South, the Netherlands	60
Great Belt East bridge, Denmark	50

Source: Flyvbjerg, (2017). Prepared by Alexandria Edwards, the Johns Hopkins University.

3.2. Deceptive cost estimation: Causes and empirical evidence

Flyvbjerg, SkarmisHolm, and Buhl identified four major steps in the academic literature that aim to better understand the role of deceptive cost estimation and decision making in project planning, with a focus on transportation infrastructure. In the 1990s, Pickrell and Fouracre, Allport, and Thomson took the first step, and both studies found evidence of substantial cost underestimation based on a small number of urban railroad projects (Flyvbjerg, Holm, & Buhl, 2002). Secondly, Wachs supported these findings and found that "intentional deception" is a fundamental cause of cost underestimation, also based on a small sample of urban rail projects (Flyvbjerg *et al.*, 2002). However, this initial research was based on sample sizes too small to be statistically significant. Flyvbjerg *et al.*, (2002) take the third step. By using a large sample of transportation infrastructure projects, they demonstrate:

1. The pattern of cost underestimation first established by Pickrell, Fouracre et al., and others is generalizable and statically significant.
2. This pattern of cost underestimation holds across different project types, geographical regions, and historical periods (Flyvbjerg *et al.*, 2002).

Moreover, they show that the large-sample pattern lends statistical support to Wachs' claim about deceptive cost underestimation in his smaller-sample study.

The fourth and final step in fully understanding cost underestimation would be to apply Wachs' analysis to a large sample of different transportation infrastructure projects to establish whether systematic deception actually takes place (Flyvbjerg *et al.*, 2002). This has not been conclusively established yet and is a topic for further research.

Flyvbjerg's (2002) study established a foundation for further research into cost inaccuracies in project planning, and his database has been referenced in numerous subsequent works. In accordance with international convention, they measure inaccurate cost estimates as "cost escalation" or "cost overrun," or actual costs minus estimated costs as a percentage of estimated costs (Flyvbjerg *et al.*, 2002). Additionally, they define estimated costs as those assessed at the time of the decision to build rather than a later stage in project development, as this method most accurately reflects the costs considered in the initial decision making process.

Using a sample of 258 transportation infrastructure projects worth $90 billion, representing diverse project types, regions, and historical periods, Flyvbjerg et al. found that cost estimates are "highly and systematically misleading." (Flyvbjerg *et al.,* 2002).

3.2.1. Inaccuracy of cost estimates

Figure 1 shows the distribution of inaccuracies of cost estimates. In almost 9 out of 10 projects, costs are underestimated. For any randomly selected project, there is an 86% chance that actual costs will exceed estimated costs, while the likelihood of actual costs being lower or equal to estimates is only 14%. Estimated costs are systematically underestimated, and by a substantially larger margin than costs that have been overestimated.

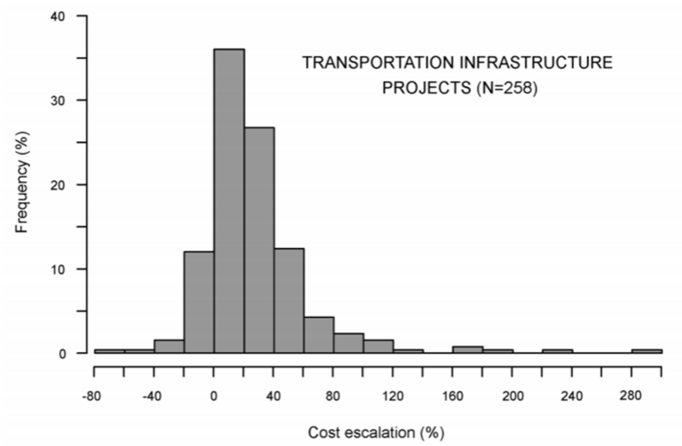

Figure 1. *Inaccuracy of cost estimates in 258 transportation infrastructure projects (fixed prices)*

Source: Flyvbjerg, Skamris. & Buhl, (2002).

3.2.2. Cost underestimation by project type

Three main project types were studied: rail projects (high speed, urban, and conventional inner-city rail), fixed-link projects (bridges and tunnels), and roads. Table 5 depicts the average expected cost inaccuracies and standard deviation by project type. The data show that rail projects incur the highest cost overruns with an average of 44.7%, followed by fixed link projects at 33.8% and roads at 20.4%. Project type has a statistically significant effect on percentage cost escalation.

Table 6. *Inaccuracy of transportation cost estimates by project type (fixed prices)*

Project type	Number of cases (N)	Average cost escalation (%)	Standard deviation	Level of significance (p)
Rail	58	44.7	38.4	<0.001
Fixed link	33	33.8	62.4	<0.004
Road	167	20.4	29.9	<0.001
All projects	91	27.6	38.7	<0.001

Source: Flyvbjerg, Holm, & Buhl, (2002). Prepared by Alexandria Edwards, the Johns Hopkins University.

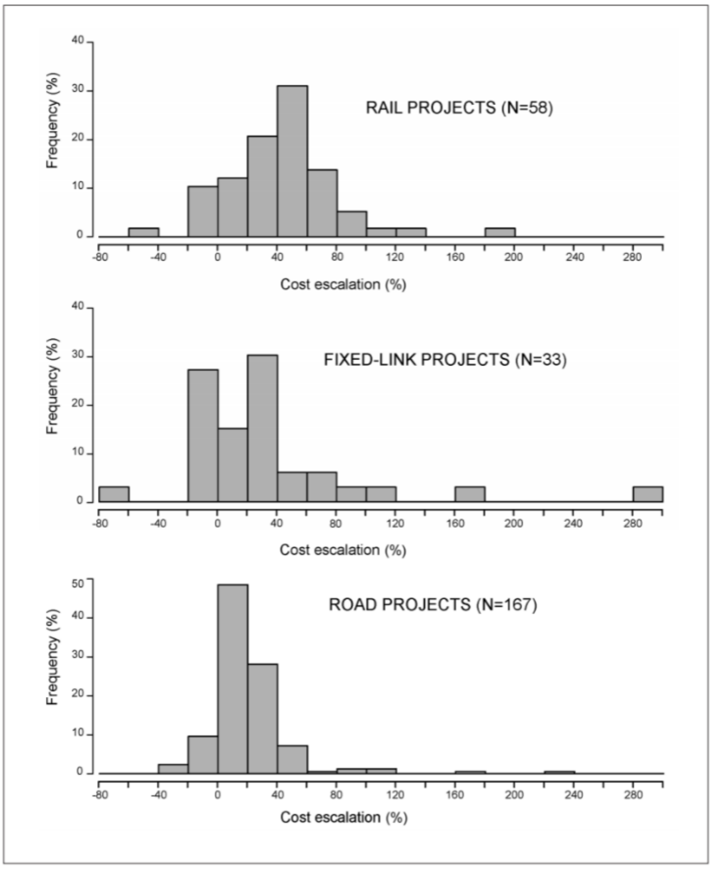

Figure 2. *Inaccuracy of cost estimates in rail, fixed-link, and road projects (fixed prices)*
Source: Flyvbjerg, Holm, & Buhl, (2002)

3.2.3. Cost underestimation by geographical location

Table 7 shows differences between actual and estimated costs for projects in Europe, North America, and "other geographical areas," including 10 developing nations plus Japan. Highly significant differences were found in countries from "other geographical areas," as the average cost escalation was 64.6%.

Table 7. *Inaccuracy of transportation project cost estimates by geographical location (fixed prices)*

	Europe			North America			Other regions		
Project type	Number of cases (N)	Average cost escalation (%)	Standard deviation	Number of cases (N)	Average cost escalation (%)	Standard deviation	Number of cases (N)	Average cost escalation (%)	Standard deviation
Rail	23	34.2	25.1	19	40.8	36.8	16	64.6	49.5
Fixed link	15	43.4	52	18	25.7	70.5	0	-	-
Road	143	22.4	24.9	24	8.4	49.4	0	-	-
All projects	181	25.7	28.7	61	23.6	54.2	16	64.6	49.5

Source: Flyvbjerg, Holm, & Buhl, (2002). Prepared by Alexandria Edwards, the Johns Hopkins University

3.2.4. Cost underestimation over time

If cost underestimation were unintentional and primarily a result of inexperience or faulty methods in forecasting costs, it would follow that cost underestimation would decrease over time as new and better methods were developed and additional experience was gained in planning and implementation. However, data show that cost underestimation has not decreased over this period and is in the "same order of magnitude as it was 10, 30, and 70 years ago. No learning seems to take place in this important and highly costly sector of public and private decision making." (Flyvbjerg, Skamris. & Buhl, 2002).

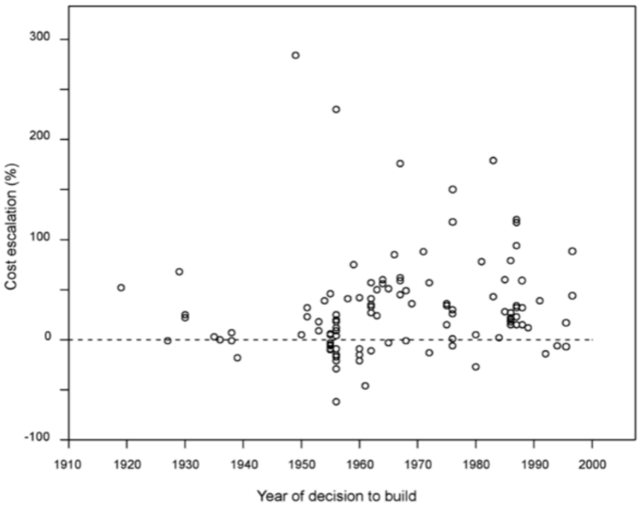

Figure 3. *Inaccuracy of cost estimates in transportation projects over time, 1910-1998 (fixed prices, 111 projects)*

Source: Flyvbjerg, Holm, & Buhl, (2002)

3.3. Geographic variation and project cost performance

Cantarelli, Flyvbjerg, & Buhl (2002) further studied the role of geographical location in cost performance and built upon Flyvbjerg's initial 2002 dataset. While cost overruns occur globally, the magnitude of overruns varies with location. The study discussed Boston's Central Artery project, the complex underground highway project known as the "Big Dig," which had cost overrun of 275%. Another famous project disaster is the United Kingdom's Channel Tunnel, resulting in 80% higher than forecasted construction costs. Despite being a global phenomenon, very few studies comparing actual and estimated costs have accounted for geographical location (Cantarelli, Flyvbjerg, & Buhl, 2012).

Numerous studies have focused on overruns in individual countries, and an overview of the current literature is included in Table 8. All these studies affirm that cost overruns are more common than under runs, however, the magnitude of overruns differs among the studies. According to Cantarelli et al., the main reason for the differences in average cost overrun is the difference in the use of nominal and real prices. Additionally, the use of different baselines for cost estimations, sample sizes, and geography contribute to the variation (Cantarelli, Flyvbjerg, & Buhl, 2012).

Table 8. *Frequency and Magnitude of Cost Overruns Found in Literature*

Study	Geographical area	Frequency cost overrun (%)	Magnitude of cost overrun							
			Road		*Rail*		*Fixed link*		*Other*	
			%	N	%	N	%	N	%	N
Merewitz (1973)	US	79	26	49	54	17				
Morris (1990)	India				164	23			4	10
Pickrell (1990, 1992)	US	88			61	8				
Auditor General (1994)	Sweden		86	8	17	7				
Nijkamp and Ubbels (1999)	Netherlands, Finland	75							0-20	8
Bordat et al. (2004)	US	55	5	2,668						
Odeck (2004)	Norway	52	8	620						
Dantata et al. (2006)	US	81			30	16				
Ellis et al. (2007)	US		9	3,130						
Lee (2008)	South Korea	95	11	138	48	16				
Flyvbjerg *et al.* (2003a)	World	86	20	167	41	58	34	33		

Prepared by Alexandria Edwards, The Johns Hopkins University.
Source: Cantarelli, Flyvbjerg, & Buhl, (2012).

3.3.1. Cost overruns in 806 projects compared with previous data

Cantarelli *et al.* (2012) also aimed to assess whether and to what extent cost performance in the enlarged global dataset differed from the data included in Flyvbjerg's original dataset of 258 projects (Flyvbjerg, Holm, & Buhl, 2002). The enlarged database of 806 projects differs from the original in three aspects:

1. Projects from three new regions are included: South Europe, East Europe and Africa.
2. Asian projects are better represented in the larger database.
3. The number of projects for all three project types has been greatly increased (Flyvbjerg, Holm, & Buhl, 2002).

Table 9 presents projects per region and project type for both databases, and Table 10 represents the number of projects, mean cost overrun, and standard deviation for both samples.

Table 9. *Number of projects (#) per region and project type in the database with 806 and 258 projects.*

Worldwide database (N = 806)						Worldwide database (N = 258)			
Region	# Road	# Rail	# Tunnel	# Bridge	#Total	# Road	# Rail	# Fixed Link	# Total
NW EU	315	90	32	22	459	143	23	15	181
S EU	16	7	–	–	23	–	–	–	0
E EU	37	–	–	–	37	–	–	–	0
N Am	24	65	3	16	108	24	19	18	61
L Am	–	1	–	–	1	–	1	–	1
Asia	138	20	1	–	159	0	3	0	3
Africa	7	–	–	–	7	–	–	–	0
Other	–	12	–	–	12	–	12	–	12
Total	537	195	36	38	806	167	58	33	258

Prepared by Alexandria Edwards, The Johns Hopkins University.
Source: Cantarelli, Flyvbjerg, & Buhl (2012).

Table 10. *Cost overruns (%) broken down by project type for worldwide samples (N = 806) and (N = 258).*

Project type	Worldwide N = 806			Worldwide N = 258		
	N	Mean (%)	SD	*N*	Mean (%)	SD
Road	537	19.8	31.4	167	20.4	29.9
Rail	195	34.1	43.5	58	44.7	38.4
Fixed Links	74	32.8	58.2	33	33.8	62.4
Bridges	38	30.3	60.6	n/a	n/a	n/a
Tunnels	36	35.5	56.3	n/a	n/a	n/a

Prepared by Alexandria Edwards, The Johns Hopkins University
Source: Cantarelli, Flyvbjerg, & Buhl, (2012).

Of the project types, road projects have the smallest overrun of 20%, followed by bridge projects with 30%, rail projects with 34%, and tunnel projects with an overrun of 35%; the authors conclude, with overwhelming statistical significance, that cost performance differs among project types. Comparing the enlarged dataset with the original, two figures are notable: the considerably lower average cost overrun for rail projects and the hardly changed cost overrun for road projects. This suggests that geographical location had a larger influence on cost overrun for rail projects than for road projects, which can be explained by the addition of projects in Europe and North America that generally have a better cost performance record.

3.4. Evaluating the "China Myth"

China's infrastructure program illustrates the accelerated pace at which nations are investing in megaprojects. For example, from 2004-2008, China spent more on infrastructure than it did during the entire twentieth century, increasing the spending rate by a factor of twenty (Ansar, Flyvbjerg, & Budzier, 2016). Additionally, China built as many kilometers of high-speed rail from 2005-2008 as Europe did in twenty years.

China's investment boom has coincided with considerable accumulation in debt, as shown in Figure 6. Total debt increased by $26.1 trillion from 2000 to 2014, with total capital investment increasing $29.1 trillion; the vast majority of Chinese investments since 2008 have been debt fueled (Ansar, Flyvbjerg, & Budzier, 2016). Accounting for the fact that many corporations and financial institutions in China are state-owned, China's implicit government debt as percentage of GDP indicates that it is the second-most indebted government in the world (Ansar, Flyvbjerg, & Budzier, 2016).

Ansar, Flyvbjerg, & Budzier (2016) conducted an *ex-post* study of infrastructure investments in China, where substantial economic growth has occurred in tandem with a sprawling infrastructure program. Using a large sample of investments, the authors sought to understand whether each of the projects generated economic value, quantified as a benefit-to-cost-ratio greater than 1.0. They studied 95 road and rail projects built from 1984 to 2008 spanning 19 (out of 22) provinces, all four municipalities, and four out of five autonomous regions, constituting the largest dataset of its kind on China's infrastructure (Ansar, Flyvbjerg, & Budzier, 2016). The primary measures used by the authors were cost performance (defined as underrun or overrun, expressed as a ratio of cost estimates), schedule performance (measured as a ratio of actual implementation period to estimated implementation period), and benefits performance (measured as forecasted vs. actualized traffic).

The evidence presents a dismal picture of the outcomes of major transport projects in China. While the typical predicted benefit-to-cost-ratio was approximately 1.4-1.5, indicating that planners expected net present benefits would exceed net present costs by 40-50%, the evidence suggests that over half of the infrastructure investments in China have actually been NPV negative over the past 30 years (Ansar, Flyvbjerg, & Budzier, 2016). Rather than driving economic growth, the typical infrastructure project has destroyed economic value.

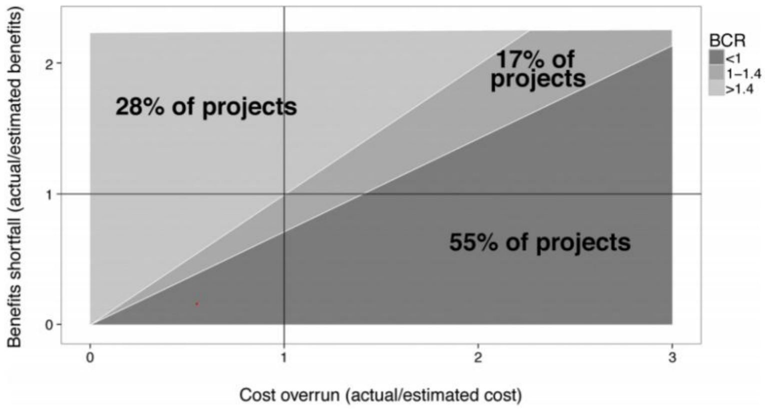

Figure 4. *Proportions of projects by ex post estimates of BCRs (n=65)*
Source: Ansar, Flyvbjerg, & Budzier, (2016).

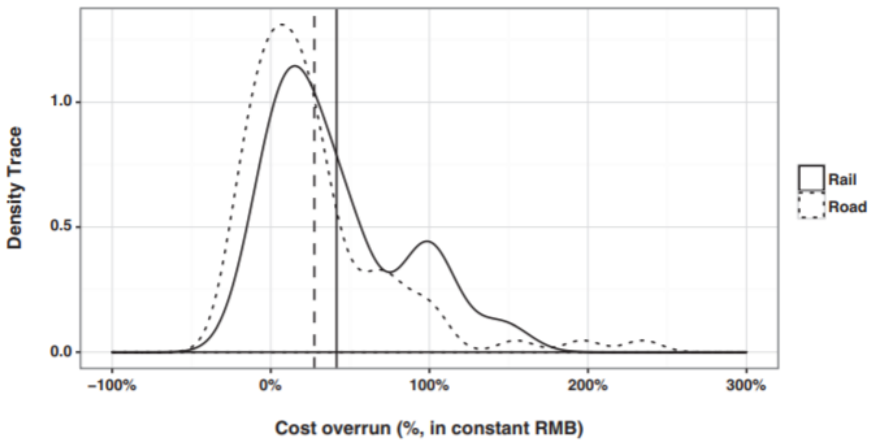

Figure 5. *Density trace of cost overruns in constant RMB by project type and mean (vertical lines) – road (n=74) and rail (n=21)*
Source: Ansar, Flyvbjerg, & Budzier, (2016).

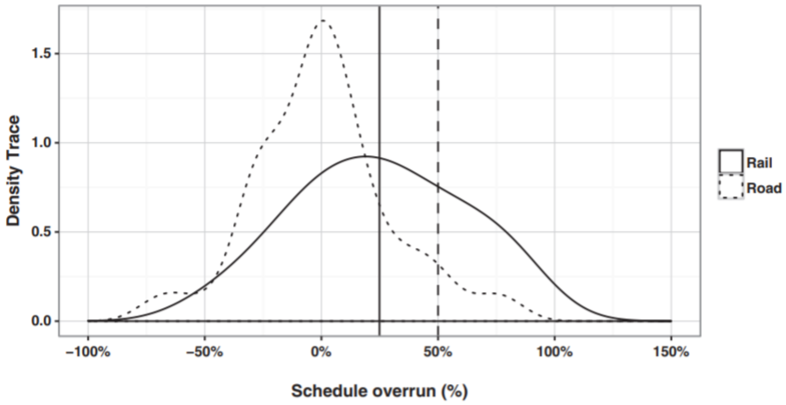

Figure 6. *Density trace of schedule overruns by project type and mean (vertical lines) – road (n=74) and rail (n=21)*
Source: Ansar, Flyvbjerg, & Budzier, (2016).

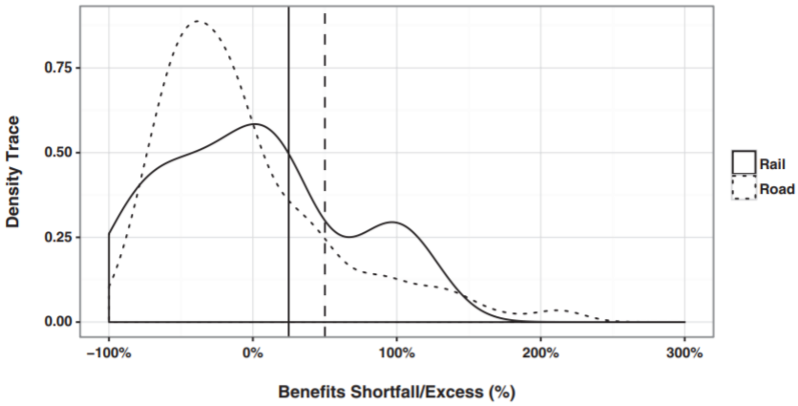

Figure 7. *Density trace of benefit shortfall or excess (%) by project type and mean (vertical lines) – road (n=137) and rail (n=19)*
Source: Ansar, Flyvbjerg, & Budzier, (2016).

While many assert that China's massive infrastructure programs explain its high growth rate, Ansar et al. and others argue that this is a fundamentally flawed interpretation. China's stellar economic performance during the 1980s preceded its infrastructure programs. The so-called 'China miracle' occurred "not because it had glittering skyscrapers and modern highways, but because bold liberalization and institutional reforms created competition and nurtured private entrepreneurship." (Huang, 2006).

Ansar *et al.*, (2016) challenge neo-Keynesian interpretations of the role of infrastructure spending, asserting that China's investment boom and poor project level outcomes have had pernicious macroeconomic implications. The consequences of over-investment in underperforming projects are amplified by the accumulation of "destabilizing piles of debt…and unprecedented monetary expansion," which has also created heightened economic fragility to financial crises (Ansar, Flyvbjerg, & Budzier, 2016).

3.5. The fallacy of beneficial ignorance – rejecting Hirschman's hiding hand

An influential principle in project planning is Albert O. Hirschman's principle of the "Hiding Hand," initially published in 1967. This principle is clearly expressed by former Speaker of the California State Assembly and Mayor of San Francisco in comments regarding the city's Transbay Terminal megaproject, a multi-billion dollar scheme that incurred substantial cost overruns: "If people knew the real cost from the start, nothing would ever be approved. The idea is to get going. Start digging."(Flyvbjerg, 2016). Hirschman's principle was first published over 50 years ago; the theory remains extremely influential in academics and policymaking. As the world is currently experiencing the "biggest investment boom in history" with project portfolios growing rapidly worldwide, this politically convenient explanation is becoming even more consequential"(Flyvbjerg, 2016).

Flyvbjerg conducted the first statistical test of this principle, which ultimately rejected the theory at a high level of significance. Moreover, his study found that in reality, the exact opposite outcomes occur – rather than obtaining project success with cost overruns outweighed by higher than estimate benefits, the average project is "undermined by a double whammy" of cost overruns and benefit shortfalls"(Flyvbjerg, 2016). Flyvbjerg (2016) notes that Hirschman's ideas are based on an "exceedingly small number of observations and biased data," citing merely 11 development projects spread over four continents (Flyvbjerg, 2016). This fact is often obscured in the secondary literature referring to this principle, giving a false sense of strong empirical foundations. Additionally, Hirschman's study is based on biased data collection. Hirschman's own notes indicate that despite the fact that project managers conveyed "that their projects had 'failed,'" he "tended to be more hopeful than his witnesses." (Flyvbjerg, 2016). While such optimism could be reasonable, the data were never systematically problematized or tested for validity, and the nature of the data collection was generally concealed (Flyvbjerg, 2016). Ultimately, the concept of the Hiding Hand was overextended as a generalizable principle.

Flyvbjerg conducted a statistical test on a dataset consisting of 2,062 projects in an attempt to replicate Hirschman's results with a greater sample, which constitutes the largest dataset of its kind. The data cover eight project types, 104 countries on six continents (including developed and developing nations), and a time period from 1927 to 2018 (Flyvbjerg, 2016). Each project was measured for cost overrun and benefit overrun. These data are difficult to come by, as no statistical agency or data service exists to obtain such information. As a result, the data were mined data point by data point directly from the source; the current dataset was compiled over 20 years. Data were obtained from various sources, including annual project accounts, cost and procurement accounts, revenue accounts, auditors' data, questionnaires, interviews, and other studies.

Additionally, some data were rejected due to insufficient data quality, so this study includes all projects for which data were deemed valid and reliable.

Flyvbjerg refutes Hirschman's main claim that higher than estimate project costs/difficulties are typically outweighed by even higher-than-estimated project benefits/problem solving abilities. While ideal data would measure the complete life cycle of projects, such data are rarely available. As a result, international convention is to measure costs by the proxy of construction costs and benefits by the proxy of first year benefits, and this convention is used in Flyvbjerg's test (Flyvbjerg, 2016). Cost overrun is measured as actual divided by estimated costs in real terms, and benefit overruns is measured by the actual divided by estimated usage (e.g., traffic for transportation infrastructure and power generation for energy infrastructure). For both cases, the baseline for determining overrun is calculated at the date of decision to build.

Table 11. *Are higher than estimated costs outweighed by even higher-than-estimated benefits, as the Hiding Hand claims?*

(Cost and benefit overruns measured as actual divided by estimated costs and benefits [A/E], in real terms)

Project Type	Cost Overruns		Benefit Overruns		
	N	Average cost overrun (A/E)	*N*	Average benefit overrun (A/E)	*p**
Dams	243	1.96	84	0.89	<0.0001
Bus Rapid Transit	6	1.41	4	0.42	0.007
Rail	264	1.4	74	0.66	<0.0001
Tunnels	48	1.36	23	0.81	0.015
Power Plants	100	1.36	23	0.94	0.0003
Buildings	24	1.36	20	0.99	0.01
Bridges	49	1.32	26	0.96	<0.0001
Roads	869	1.24	532	0.96	<0.0001
Total	1603	1.39/1.43**	786	0.9/0.83**	<0.0001

Notes: * The p-value of the test with the null hypothesis that benefit overrun is larger than cost overrun, using Mann-Whitney test. **Weighted and unweighted average, respectively.
Source: Flyvbjerg (2016).

If Hirschman's principle were correct, average benefit overruns would exceed average cost overruns – this is not the case for any of the eight project types in Table 1. Moreover, there is no benefit overrun at all – in fact, Flyvbjerg found an average benefit shortfall (benefit overrun <1). Rather than developing projects that generate benefits compensating for cost overruns, as theorized in Hirschman's "two offsetting underestimates," the average project is "impaired by a twofold blow of substantial cost overruns compounded by substantial benefit shortfalls." (Flyvbjerg, 2016). Not only is this pattern bad for general viability at the project level, but just one major project gone awry can have detrimental impacts on fragile national economies.

3.6. Costs of hydropower megaproject development

A growing area of megaproject development includes hydropower dams. In light of this "brisk building boom of hydropower mega-dams" worldwide, Ansar et al. investigated *ex post* outcomes of schedule and cost estimates (Ansar, Flyvbjerg, Budzier, & Lunn, 2014). The authors found overwhelming evidence that budgets are systematically biased below actual costs, yet in most countries, large hydropower dams will be too costly and take too long to build to deliver positive risk-adjusted returns without appropriate risk management measures. Proponents of large dams cite numerous benefits – reduced use of fossil fuels, flood control, urban water supply, and job creation, among others. Thus, there has been a "robust pipeline of new mega-dams" of unprecedented scale being developed globally after a two-decade lull (Ansar, *et al.*, 2014). Despite these purported benefits, large dams are controversial because they entail substantial financial costs, as well as profound environmental, ecological, and social impacts.

Furthermore, these projects are so large in scale that even for an economy as large as China's, the "negative economic ramifications could likely hinder the economic viability of the country as a whole" if risks are not adequately managed (Ansar, *et al.*, 2014). Increasingly, evidence in civil society, academia, and institutional accounts has suggested that large dams have "strikingly poor performance record in terms of economic, social and environmental impact, and public support." Ansar *et al.*, (2014) aim to answer the question: should we build more large hydropower dams?

Ansar *et al.*, (2014) conducted an investigation and multilevel regression analysis centered on the magnitude and frequency of inaccuracies between managers' forecasts and actual outcomes related to cost overrun and schedule overrun. The authors used multilevel regression models in order to address the fact that outcomes of dam projects may exhibit within-country country correlations. Using data from 245 large dams and 36 potential explanatory variables, Ansar et al. made the following observations: (Ansar, *et al.*, 2014).

1. Three out of every four large dams suffered cost overrun in constant local currency terms.
2. Actual costs, on average, were 96% higher than estimated costs, with a median of 27%. The evidence overwhelmingly supports a systematic bias toward cost underestimation; the magnitude of cost overrun is higher than the error of cost overestimation.
3. As depicted in Figure 8, Graphing cost overrun reveals a fat tail, implying that planners have difficulty in computing probabilities of events far into the future. Actual costs more than double for two out of every ten large dams, and more than triple for one out of every ten dams.
4. As depicted in Figure 9, large dams in every region of the world suffer systematic cost overrun. Large dams build in North America (N=40) have considerably lower average cost overrun (11%) than dams build elsewhere (104%). After controlling for covariates such as project scale in a multilevel model, Ansar et al. have found that differences among regions are not significant. One potential explanation may be that 3 out of 4 dams in this study were advised by North American firms, and as a result, an

"overreliance on North American experience" may bias cost estimates downwards in the rest of the world.

5. The typical projected benefit-to-cost ratio was 1.4; planners expected net present benefits to exceed net present costs by 40%. Nearly half of the dams suffered actual cost overrun of 1.4 or greater.

6. The authors studied whether forecasting errors differ by project type (e.g., hydropower, irrigation, or multipurpose dam) or wall type. They found no statistically significant differences.

7. After analyzing whether cost estimates have increased accuracy over time, Ansar et al. found that irrespective of the year or decade in which a dam is built, there are no significant differences in forecasting errors (Figure 2). Additionally, there is no linear trend suggesting improvement or deteriorating forecasts over time; there is little learning from prior mistakes.

8. Eight out of every 10 large dams suffered schedule overrun.

9. Actual implementation schedule, on average, exceeded the estimate by 44%, with a median of 27%, shown in Figure 11. Evidence overwhelmingly suggests that implementation schedules are systematically biased toward underestimation, like cost overruns; the magnitude of schedule underestimation is larger than the error of schedule overestimation.

10. Costs are at a higher risk of "spiraling out of control" than schedules. While graphing schedule overruns also reveals a fat tail as shown in Figure 11, it is not as fat as the tail of cost overruns.

11. There is less regional variation in schedule overruns than cost overruns; large dams built everywhere take significantly longer than forecasted.

12. There is no evidence indicating that schedule estimates have improved over time.

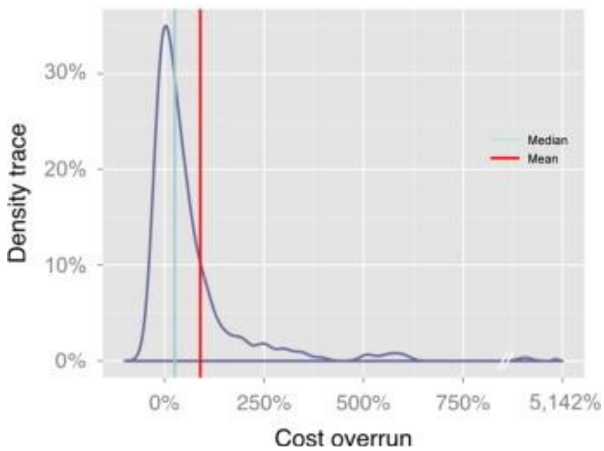

Figure 8. *Density trace of actual/estimated cost (i.e. costs overruns) in constant local currency terms with the median and mean (N=245).*

Source: Ansar, *et al.*, (2014).

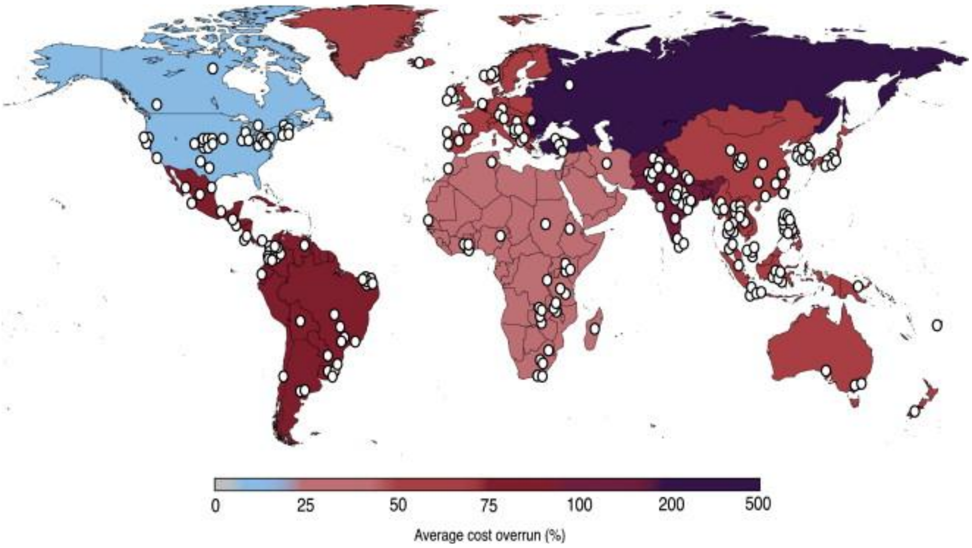

Figure 9. *Location of large dams in the sample and cost overruns by geography.*
Source: Ansar, *et al.*, (2014).

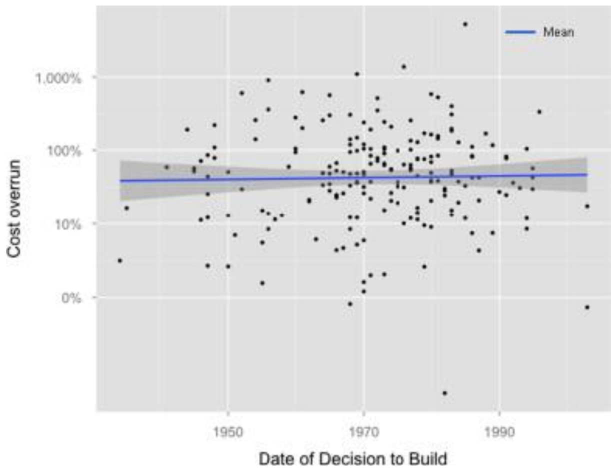

Figure 10. *Inaccuracy of cost estimates (local currencies, constant prices) for large dams over time (N=245), 1934–2007.*
Source: Ansar, *et al.*, (2014).

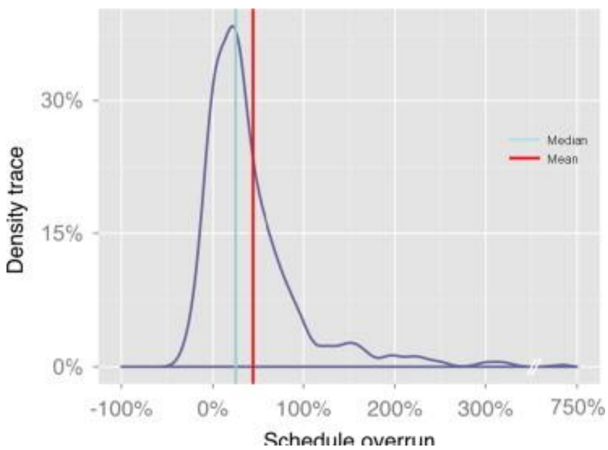

Figure 11. *Inaccuracy of schedule estimates (local currencies, constant prices) for large dams over time (N=245), 1934–2007.*
Source: Ansar, *et al.*, (2014).

In light of these observations and analysis of numerous qualitative case examples, Ansar et al. put forth four policy propositions to avert substantial cost and schedule overruns:

1. Energy alternatives that rely on fewer site-specific characteristics, such as unfavorable geology, are preferable.

In projects around the world, experts' optimism regarding numerous risk factors exacerbate cost overruns in large dams. The planning documents for Brazil's Itumbiara hydroelectric project demonstrate this. Despite recognizing that the site chosen was geologically unfavorable, the plan optimistically provided 20% of base cost for physical contingencies; in reality, weak geology resulted in costs of 96% of the base cost, in real terms (Ansar, *et al.,* 2014).

2. *Energy alternatives that rely on fewer imports or match the currency of liabilities with the currency of future revenue are preferable.*

Planners of Colombia's Chivor hydroelectric project were optimistic that the exchange rate between the Colombian Peso and the US dollar would not change during the project's seven-year construction period (1970-1977), providing no allowance for potential future exchange rate fluctuations. In reality, the Colombian peso depreciated nearly 90% against the US dollar, resulting in a 32% cost overrun in real Colombian peso terms. Currency exposure is a consistent "fiscal hemorrhage" for large projects (Ansar, *et al.,* 2014).

3. *The best insurance against creeping inflation is to reduce the implementation schedule to as short a horizon as possible. Energy alternatives that can be built sooner and with lower risk of schedule overruns, e.g. through modular design, are preferable.*

Following convention, Ansar et al.'s analysis excludes effects of inflation. However, planners must consider the risks of unanticipated inflation – episodes of hyperinflation in Argentina, Brazil, Turkey, and Yugoslavia resulted in "staggering nominal cost overruns" of up to 110-times the initial budget (as seen in Yugoslavia's Visegrad dam from 1985-1990), which had to be financed with additional debt (Ansar, *et al.,* 2014). These effects are magnified by long project completion periods.

4. Energy alternatives that do not constitute a large proportion of the balance sheet of a country or a company are preferable. Similarly, policymakers, particularly in countries at lower levels of economic development, ought to avoid highly leveraged investments denominated in a mix of currencies.

Large dams are generally financed by public borrowing. Cost overruns increase nations' stock of debt, as well as recurring financing costs that escalate if interest rates increase. For instance, the Tarbela dam amounted to 23% of the increase in Pakistan's external public debt from 1968 to 1984 (Ansar, *et al.,* 2014). Ultimately, major projects entail uncontrollable risks which cannot adequately hedged, even when anticipated.

Before making any investment in a project, policymakers should refer to a valid and reliable "outside view, or reference class forecast (RCF) that can predict the outcome of a planned investment" based on actual historical outcomes in a reference class of similar, previously completed cases (Flyvbjerg, 2008). The application of RCF techniques to energy investments, as well as infrastructure more broadly, will enhance transparency of risk profiles of various alternatives on the basis of not only financial costs and benefits, but also environmental and social impacts, and improve resource allocation through an "outside-in view to estimate costs, benefits, time, and broader impacts" while mitigating the effects of optimism bias and strategic misrepresentation (Flyvbjerg, 2008). Ideally, a comprehensive global dataset would create transparency on risk profiles of alternative investment opportunities.

4. Conclusion

Governments around the globe are pouring billionsin to massive public works projects in a seemingly bipartisan consensus, and politicians across the political spectrum have called for unprecedented levels of public spending on infrastructure and other government projects. However, policymakers have failed to consider the fact that despite massive spending, project performance is systematically substandard, often threatening the financial viability of these initiatives and eroding, rather than creating value for taxpayers. Lacking comprehensive, *ex-post* cost-benefit analysis, political and bureaucratic motivations distort the decision-making process regarding major projects. Moreover, overinvestment in underperforming projects, especially when compounded by high levels of debt, can result in systemic fragility. The sheer size of megaprojects is also concerning. If they were nations, projects of this size would rank among the world's top 100 countries based on GDP; when such massive projects fail, there are substantial economic implications. The private sector profit and loss system of accountability and incentive alignment is lacking in most aspects of government investment, and this is abundantly clear in the infrastructure story. Rather than a system of purely economic calculations, bureaucratic management is "dependent on definite detailed rules and regulations" and often skewed by political interests (Mises, 1951).

As the economy grapples with recession in the wake of the Covid-19 pandemic, governments worldwide have spentup wards of $8 trillion in fiscal stimulus and adopted unprecedented monetary policy measures. There have been bipartisan calls fora major infrastructure program as part of the next stimulus plan, on top of the roughly $2 trillional located thus far. House Democrats have proposed a sprawling $1.5 trillion "infrastructure" plan covering everything from roads to education, housing, clean water, broadband, and other largely unrelated items (Wolfe, 2020). Policy makers should carefully consider projects on the basis of economic needs and look to policies that allow the private sector to drive growth, rather than waste trillions of taxpayer dollars on projects plagued by cost overruns and bureaucratic mismanagement.

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