EDITED BY
BENT
FLYVBJERG

The Oxford Handbook *of* MEGAPROJECT MANAGEMENT

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CHAPTER 1

INTRODUCTION

The Iron Law of Megaproject Management

BENT FLYVBJERG

1.1 Classics in Megaproject Management

The ambition for this inaugural edition of *The Oxford Handbook of Megaproject Management* is to become the ultimate source for state-of-the-art scholarship in the emerging field of megaproject management. The book offers a rigorous, research-oriented, up-to-date academic view of the discipline based on high-quality data and strong theory. Until lately, the literature in this new field was scattered over a large number of publications and disciplines, making it difficult to obtain an overview of the history, key issues, and core readings. *Megaproject Planning and Management: Essential Readings* (Flyvbjerg 2014a) assembled the central historical texts in the field. *The Oxford Handbook of Megaproject Management* has been designed to provide the most important contemporary readings. Taken together, the two books are intended to map out the best of what is worth reading in the megaproject management literature, past and present.

In a recent survey, the author asked 114 experts to identify the classics in megaproject management (Flyvbjerg 2014b: xxx–xxxi). The results show that if one defines a "classic" in the conventional sense—as a written work that is generally recognized as definitive in its field by a majority of experts in that field—then there are no classics in megaproject management. Remarkably, the publication proposed by the most respondents as a classic was proposed by only five respondents—several times less the required majority for a classic. In no less than 79% of cases, a publication put forward as a classic was proposed by one and only one respondent, indicating a huge spread in views regarding what the classics might be in this field.

Several explanations exist for this lack of consensus regarding classics in megaproject management. The field is young and unconsolidated as an academic discipline; therefore, perhaps more time is needed to develop and agree upon possible classics. Moreover, the field is multidisciplinary and fragmented, which makes consensus harder to come by. Whatever the explanation, Kuhn (2012) and other philosophers of science hold that classics are necessary to develop and strengthen an academic field, because classics serve as exemplars and reference points around which paradigmatic research may evolve and against which revolutionary research can pit itself. Following Kuhn and others, it is argued here that megaproject management, if it is to make progress as an academic field of inquiry and a professional field of practice, is very much in need of classics. *The Oxford Handbook of Megaproject Management* together with the previous book of historical texts have therefore been developed with the explicit purpose of contributing to the growth of such classics, and hopefully one or more papers in these books may one day become classics.

In addition to the print version of *The Oxford Handbook of Megaproject Management*, an electronic version is planned to ensure the widest possible dissemination and to allow updates as new research appears.[1] The primary audience for the book is the research academic community, professionals, doctoral students, master's programs, and executive education programs in management, strategy, planning, megaproject management, and project and program management. It is hoped that by providing the present set of cutting-edge contemporary readings in megaproject management the book will help progress the discipline, academically and professionally. It is also hoped that citizens and communities interested in and affected by megaprojects may find useful insights in this book.

1.2 What Are Megaprojects?

Megaprojects are large-scale, complex ventures that typically cost $1 billion or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people.[2] Hirschman (1995: vii, xi) calls such projects "privileged particles of the development process" and points out that often they are "trait making;" that is, they are designed to ambitiously change the structure of society, as opposed to smaller and more conventional projects that are "trait taking"—they fit into and follow pre-existing structures and do not attempt to modify them. Megaprojects, therefore, are not just magnified versions of smaller projects. Megaprojects are a completely different breed of project in terms of their level of aspiration, stakeholder involvement, lead times, complexity, and impact. Consequently, they are also a very different type of project to lead. Conventional project managers should not lead megaprojects. Megaprojects require reflective practitioners (Schön 1983) as leaders who have developed deep domain experience in this specific field.

Megaprojects are increasingly used as the preferred delivery model for goods and services across a range of businesses and sectors, such as infrastructure, water and energy, information technology, industrial processing plants, mining, supply chains, enterprise systems, strategic corporate initiatives and change programs, mergers and acquisitions, government administrative systems, banking, defense, intelligence, air and space exploration, big science, urban regeneration, and major events (Chapter 2, Lenfle and Loch; Chapter 3, Siemiatycki). Examples of megaprojects are high-speed rail lines, airports, seaports, motorways, disease or poverty eradication programs, hospitals, national health or pension ICT systems, national border control, national broadband, the Olympics, large-scale signature architecture, dams, wind farms, server farms, offshore oil and gas extraction, aluminum smelters, the development of new aircrafts, the largest container and cruise ships, high-energy particle accelerators, and the logistics systems used to run large supply-chain-based companies such as Apple, Amazon, and Maersk.

To illustrate just how big megaprojects are, consider that in dollar terms some of the largest projects are as big as the GDP of many nations (Figure 1.1). Or take one of the largest dollar figures from public economic debate: the size of the US debt to China. This debt is just north of a US$1 trillion and is considered so large that it may destabilize the world economy if it is not managed prudently. With this supersize measuring rod, now consider the fact that the combined cost of just two of the world's largest megaprojects—the Joint Strike Fighter aircraft program and China's high-speed rail project—is more than half of this figure. The cost of a mere handful of the world's largest megaprojects will dwarf almost any other economic figure, and certainly any investment figure. Finally, consider that in delivering a megaproject one has to—over a relatively short period of time—set up, run, and take down a temporary organization that is often the size of a billion-dollar corporation. The size of megaprojects is staggering no matter what the comparison, and is matched only by the challenges of managing one.

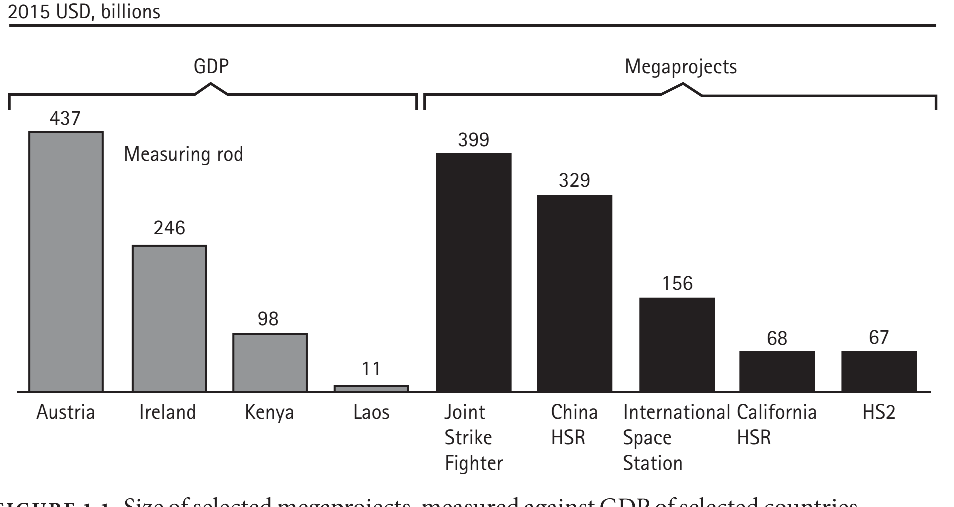

FIGURE 1.1 Size of selected megaprojects, measured against GDP of selected countries.

But megaprojects are not just large; they are constantly growing ever larger in a long historical trend with no end in sight. When New York's Chrysler Building opened in 1930 at 319 meters it was the tallest building in the world. The record has since been surpassed seven times, and from 1998 the tallest building has significantly been located in emerging economies, with Dubai's Burj Khalifa presently holding the record at 828 meters. That is a 160% increase in building height over eighty years. Similarly, the longest bridge span has grown even faster, by 260% over approximately the same period. Measured by value, the size of infrastructure projects has on average grown by 1.5–2.5% annually in real terms over the past century, which is equivalent to a doubling in project size two to three times per century (author's megaprojects database). The size of ICT projects, the new kid on the block, has grown much faster, as illustrated by a sixteen-fold increase from 1993 to 2009 in lines of code in Microsoft Windows, from five to eighty million lines. Other types of megaprojects, from the Olympics to industrial projects, have seen similar developments. Coping with increased scale is therefore a constant and pressing issue in megaproject management, as emphasized by Ansar et al. (Chapter 4). With increasing scale comes increasing globalization, and a set of institutional issues related to this (Chapter 5, Levitt and Scott).

"Mega" derives from the Greek word *megas* and means great, large, vast, big, high, tall, mighty, and important. As a scientific and technical unit of measurement, "mega" specifically means a million. If we were to use this unit of measurement in economic terms, then strictly speaking, megaprojects would be million-dollar (or euro, pound, or other) projects, and for more than a hundred years the largest projects in the world were indeed measured mostly in the millions. This changed with World War II, the Cold War, and the Space Race. Project costs now escalated to the billions, led by the Manhattan Project (1939–46), a research and development program that produced the first atomic bomb, and later the Apollo program (1961–72), which landed the first humans on the moon (Morris 1994; Flyvbjerg 2014b). According to Merriam-Webster, the first known use of the term "megaproject" was in 1976, but before that, from 1968, "mega" was used in "megacity" and later, from 1982, as a standalone adjective to indicate "very large."

Thus the term *megaproject* came into use just as the largest projects technically were megaprojects no more, but, to be accurate, "gigaprojects"—"giga" being the unit of measurement meaning a billion. However, the term *gigaproject* has not caught on. A Google search reveals that the word *megaproject* is used more frequently on the Web than the term *gigaproject*.[3] For the largest of this project type, costs of $50–100 billion are now common, as for the California and UK high-speed rail projects, and costs above $100 billion not uncommon, as for the International Space Station and the Joint Strike Fighter. If they were nations, projects of this size would rank among the world's top hundred countries measured by gross domestic product—larger than the economies of, for example, Kenya or Guatemala. When projects of this size go wrong, whole companies and national economies are affected.

"Tera" is the next unit up, as the measurement for a trillion (a thousand billion). To illustrate how the numbers scale, consider that one million seconds ago, compared with the present, is twelve days in the past; a billion seconds is thirty-two years in the past; and a trillion seconds is 31,710 years in the past, or the equivalent of several ice ages. Recent developments in the size of the very largest projects and programs indicate that we may presently be entering the "tera era" of large-scale project management. Owing to large cost overruns, the Joint Strike Fighter program looks to become the first stand-alone "teraproject" in human history, measured on life-cycle costs (United States Government Accountability Office 2012). Similarly, if we consider as projects the stimulus packages that were launched by the United States, Europe, and China to mitigate the effects of the 2008 financial and economic crises, then these are teraprojects too. Finally, if the major acquisition program portfolio of the United States Department of Defense—which was valued at $1.6 trillion in 2013—is considered a large-scale project, then this, again, would be a teraproject (United States Government Accountability Office 2013: 2). Projects of this size compare with the GDP of the world's top twenty nations, similar in size to the national economies of, for example, Australia or Canada. There is no indication that the relentless drive to scale is abating in megaproject development. Quite the opposite; scale seems to be accelerating. Megaprojects are growing ever larger.

1.3 How Big Is the Global Megaprojects Business?

Megaprojects are not only large and growing constantly larger; they are also being built in ever greater numbers at ever greater value. The McKinsey Global Institute (2013) estimates global infrastructure spending at US$3.4 trillion per year through 2013–2030, or approximately 4% of total global gross domestic product, mainly delivered as large-scale projects. *The Economist* (7 June 2008: 80) has similarly estimated infrastructure spending in emerging economies at US$ 2.2 trillion annually for the period 2009–2018.

To illustrate the accelerated pace at which spending is taking place, consider that China used more cement in the three years 2011–13 than the United States in the entire twentieth century. Similarly, in a recent five-year period China spent more on infrastructure in real terms than in the whole of the past century (Flyvbjerg 2014b). That is an increase in spending rate of a factor of twenty. Finally, in a recent four-year period China built as many kilometers of high-speed rail as Europe did in two decades, and Europe was extraordinarily busy building this type of rail during these years (Chapter 7, Ren). Not at any time in the history of mankind has infrastructure spending been this high measured as a share of world GDP, according to *The Economist*, who calls it "the biggest investment boom in history." And that is just infrastructure.

If we include the many other fields where megaprojects are a main delivery model—oil and gas, mining, aerospace, defense, ICT, supply chains, megaevents, and so on—then a conservative estimate for the global megaproject market is US$ 6–9 trillion per year, or approximately 8% of total global gross domestic product. For perspective, consider that this is equivalent to spending five to eight times the accumulated US debt to

China, *every year*. That is big business by any definition of the term. Moreover, megaprojects have proven remarkably recession-proof. In fact, the downturn from 2008 helped the megaprojects business to grow further by showering stimulus spending on everything from transportation infrastructure to ICT. From being a fringe activity—albeit a spectacular one—mainly reserved for rich, developed nations, megaprojects have recently transformed into a global multi-trillion-dollar business that affects all aspects of our lives, from our electricity bill to what we do on the Internet to how we work and shop and commute.

With so many resources tied up in ever larger and ever more megaprojects, at no time has the management of such projects been more important. The potential benefits of building the right projects in the right manner are enormous and are only equaled by the potential waste from building the wrong projects, or building projects wrongly. Never has it been more important to choose the most fitting projects and get their financial, economic, social, and environmental impacts right. Never has systematic and valid knowledge about megaprojects therefore been more important to inform policy, practice, and public debate in this very costly area of government and business. *The Oxford Handbook of Megaproject Management* is dedicated to delivering such knowledge.

1.4 Ten Things you Must Know about Megaprojects

What drives the megaproject boom described above? Why are megaprojects so attractive to decision makers? The answer to these questions may be found in the so-called four sublimes of megaproject management (Table 1.1). The first of these,

Table 1.1 The "four sublimes" that drive megaproject development

Type of sublime	Characteristic
Technological	The excitement engineers and technologists get in pushing the envelope for what is possible in "longest–tallest–fastest" type of projects.
Political	The rapture politicians get from building monuments to themselves and their causes, and from the visibility this generates with the public and media.
Economic	The delight business people and trade unions get from making lots of money and jobs from megaprojects, including for contractors, workers in construction and transportation, consultants, bankers, investors, landowners, lawyers, and developers.
Aesthetic	The pleasure designers and people who love good design get from building and using something very large that is also iconic and beautiful, such as the Golden Gate bridge.

the "technological sublime," is a term variously attributed to Miller (1965) and Marx (1967) to describe the positive historical reception of technology in American culture during the nineteenth and early twentieth centuries. Frick (2008) introduced the term to the study of megaprojects and here describes the technological sublime as the rapture engineers and technologists obtain from building large and innovative projects, with their rich opportunities for pushing the boundaries for what technology can do, such as building the tallest building, the longest bridge, the fastest aircraft, the largest wind turbine, or the first of anything (see also Chapter 10, Miller et al.; Chapter 20, Holzmann et al.) Frick (2008) applied the concept in a case study of the multi-billion-dollar New San Francisco–Oakland Bay Bridge, concluding that "the technological sublime dramatically influenced bridge design, project outcomes, public debate, and the lack of accountability for its [the bridge's] excessive cost overruns" (239).

Flyvbjerg (2012, 2014b) proposed three additional sublimes, beginning with the "political sublime," which here is understood as the rapture politicians obtain from building monuments to themselves and their causes (Chapter 13, Baade and Matheson; Chapter 24, van der Westhuizen). Megaprojects are manifest; they garner attention and lend an air of proactiveness to their promoters. Moreover, they are media magnets, which appeals to politicians who seem to enjoy few things better than the visibility they get from starting megaprojects; except maybe cutting the ribbon of one in the company of royals or presidents who are likely to be present, lured by the unique monumentality and historical import of many such projects. This is the type of public exposure that helps politicians get re-elected. They therefore actively seek it out.

Next there is the "economic sublime," which is the delight financiers, business people, and trade unions get from making lots of money and jobs from megaprojects. Given the enormous budgets for megaprojects, there are ample funds to go around for all, including contractors, engineers, architects, consultants, construction and transportation workers, bankers, investors, landowners, lawyers, and developers. Finally, the "aesthetic sublime" is the pleasure designers and people who appreciate good design get from building, using, and looking at something very large that is also iconically beautiful, such as San Francisco's Golden Gate bridge or Sydney's Opera House.

All four sublimes are important drivers of the scale and frequency of megaprojects described above. Taken together they ensure that there exist strong coalitions of stakeholders who benefit from megaprojects and who will therefore work for more such projects to happen.

For policy makers, investment in infrastructure megaprojects seems particularly coveted, because, if done right, such investment (i) creates and sustains employment, (ii) contains a large element of domestic inputs relative to imports, (iii) improves productivity and competitiveness by lowering producer costs, (iv) benefits consumers through higher-quality services, and finally, (v) improves the environment when infrastructures that are environmentally sound replace infrastructures that are not (Helm 2008: 1; Chapter 11, Clegg et al.).

But there is a big "if" here, indicated previously with the words "if done right." Only if this is disregarded—as it often is by promoters and decision makers for megaprojects—can megaprojects be seen as an effective way to deliver infrastructure. In fact, conventional megaproject delivery—infrastructure and other—is highly problematic, with a dismal performance record in terms of actual costs and benefits, as we will see later. The following characteristics of megaprojects are typically overlooked or glossed over when the four sublimes are at play and the megaproject format is chosen for delivery of large-scale ventures:

1. Megaprojects are inherently risky because of long planning horizons and complex interfaces (Flyvbjerg 2006; Chapter 21, Davies).
2. Often projects are led by planners and managers without deep domain experience, who keep changing throughout the long project cycles that apply to megaprojects, leaving leadership weak.
3. Decision making, planning, and management are typically multi-actor processes involving multiple stakeholders, public and private, with conflicting interests (Chapter 6, van Wee and Priemus; Chapter 15, Winch; Aaltonen and Kujala 2010).
4. Technology and designs are often non-standard, leading to "uniqueness bias" among planners and managers, who tend to see their projects as singular, which impedes learning from other projects.[4]
5. Frequently there is overcommitment to a certain project concept at an early stage, resulting in "lock-in" or "capture," leaving alternatives analysis weak or absent, and leading to escalated commitment in later stages. "Fail fast" does not apply; "fail slow" does (Chapter 9, Drummond; Cantarelli et al. 2010; Ross and Staw 1993).
6. Because of the large sums of money involved, principal-agent problems and rent-seeking behavior are widespread, as is optimism bias (Eisenhardt 1989; Stiglitz 1989; Flyvbjerg et al. 2009).
7. The project scope or ambition level will typically change significantly over time.
8. Delivery is a high-risk, stochastic activity, with overexposure to so-called black swans; that is, extreme events with massively negative outcomes (Taleb 2010). Managers tend to ignore this, treating projects as if they exist largely in a deterministic Newtonian world of cause, effect, and control.
9. Statistical evidence shows that such complexity and unplanned events are often unaccounted for, leaving budget and time contingencies for projects inadequate.
10. As a consequence, misinformation about costs, schedules, benefits, and risks is the norm throughout project development and decision making. The result is cost overruns, delays, and benefit shortfalls that undermine project viability during project delivery and operations.

In Section 1.5, we will see just how big and frequent such cost overruns, delays, and benefit shortfalls are.

1.5 The Iron Law of Megaprojects

Performance data for megaprojects speak their own language. Of such projects, 70–90% have cost overruns, depending on project type. For some projects, such as the Olympics, 100% have cost overruns. Overruns of up to 50% in real terms are common, and over 50% not uncommon. Cost overrun for London's Jubilee Line Underground extension was 80% in real terms; for Denver International Airport, 200%; Boston's Big Dig, 220%; the Canadian Firearms Registry, 590%; Sydney Opera House, 1,400%. Overrun is a problem in private, as well as public sector projects, and things are not improving; overruns have stayed high and constant for the 90-year period for which comparable data exist (Chapter 8, Flyvbjerg; Chapter 16, Hodge and Greve; Chapter 23, Chung). Geography also does not seem to matter; all 104 countries and six continents for which data are available suffer from overrun. Similarly, large benefit shortfalls are common, again with no signs of improvements over time and geographies (Flyvbjerg et al. 2002, 2005).

Combine the large cost overruns and benefit shortfalls with the fact that business cases, cost-benefit analyses, and social and environmental impact assessments are typically at the core of planning and decision making for megaprojects, and we see that such analyses can generally not be trusted. For instance, for dams an average cost overrun of 96% combines with an average demand shortfall of 11%, and for rail projects an average cost overrun of 40% combines with an average demand shortfall of 34%. With errors and biases of such magnitude in the forecasts that form the basis for business cases, cost–benefit analyses, and social and environmental impact assessments, such analyses will also, with a high degree of certainty, be strongly misleading. "Garbage in, garbage out," as the saying goes (Flyvbjerg 2009; for in-depth studies of dams, see Chapter 19, Scudder; Chapter 25, Ahlers et al.).

As a case in point, consider the Channel Tunnel, the longest underwater rail tunnel in Europe, connecting the United Kingdom and France. This project was originally promoted as highly beneficial both economically and financially. At the initial public offering, Eurotunnel, the private owner of the tunnel, tempted investors by telling them that 10% "would be a reasonable allowance for the possible impact of unforeseen circumstances on construction costs."[5] In fact, capital costs went 80% over budget, and financing costs 140%. Revenues started at a dismal 10% of those forecast, eventually growing to half of the forecast. As a consequence, the project has proved financially non-viable, with an internal rate of return on the investment that is negative, at –14.5%, with a total loss to Britain of US$17.8 billion. Thus the Channel Tunnel has detracted from the British economy instead of adding to it. This is difficult to believe when you use the service, which is fast, convenient, and competitive compared with alternative modes of travel. But in fact each passenger is heavily subsidized–not by the taxpayer, as is often the case for other megaprojects, but by the many private investors who lost billions when Eurotunnel went insolvent and was financially restructured. This drives home an important point. A megaproject may well be a technological success but a financial failure, and many are. An economic and financial *ex post* evaluation of the Channel Tunnel, which systematically compared actual with forecast costs and benefits, concluded that "the British Economy would have been better off had the Tunnel never been constructed" (Anguera 2006: 291). Other examples of financially non-viable megaprojects are Sydney's Lane Cove Tunnel, the high-speed rail connections at Stockholm and Oslo airports, the Copenhagen Metro, Denmark's Great Belt Tunnel—the second longest underwater rail tunnel in Europe after the Channel Tunnel, and the Chinese projects described in Ansar et al. (2016) (Table 1.2) (see also Chapter 17, Vickerman).

Large-scale ICT projects are even more risky. One in six such projects become a statistical outlier in terms of cost overrun, with an average overrun for outliers of 200% in real terms. This is a 2,000% overincidence of outliers compared to normal, and a 200% overincidence compared with large construction projects, which are also plagued by cost outliers (Flyvbjerg and Budzier 2011). Given the central role of large-scale ICT projects in many transforming organizations in both government and business, the prevalence of ICT cost outliers are ticking time bombs under such transformations, waiting to go off. Total project waste from failed and underperforming ICT projects for the United States alone has been estimated at $55 billion annually by the Standish Group (2009).

Delays are a separate problem for megaprojects, and delays cause both cost overruns and benefit shortfalls. For instance, results from a study undertaken at Oxford University, based on the largest database of its kind, shows that delays on dams are 45% on average (Ansar et al. 2014). Thus if a dam was planned to take ten years to execute, from the decision to build until the dam became operational, then it actually took 14½ years on average. Flyvbjerg et al. (2004) modeled the relationship between cost overrun and length of implementation phase based on a large dataset for major construction projects. They found that on average a one-year delay or other extension of the implementation phase correlates with an increase in percentage cost overrun of 4.64%. To illustrate, for a project the size of London's $26-billion Crossrail project, a one-year delay would cost an additional $1.2 billion, or $3.3 million per day. The key lesson here is that in order to keep costs down, implementation phases should be kept short and delays small. This should not be seen as an excuse for fast-tracking projects; that is, rushing them through decision making for early construction start. All you do if you hit the ground running is fall, in the case of megaprojects. Front-end planning needs to be thorough before deciding whether to give the green light to a project or stop it (Williams and Samset 2010). You need to go slow at first (during project preparation) in order to run fast later (during delivery). But often the situation is the exact opposite. Front-end planning is rushed and deficient, bad projects are not stopped, implementation phases and delays are long, costs soar, and benefits and revenue realization diminishes and recedes into the future. For debt-financed projects this is a recipe for disaster, because project debt grows while there are no revenues to service interest payments, which are then added to the debt, and so forth. As a result, many projects end up in the so-called debt trap where a combination of escalating construction costs, delays, and increasing interest payments makes it impossible for project revenues to cover costs, rendering projects non-viable. That is what happened to the Channel Tunnel and Sydney's Lane Cove Tunnel, among many other projects.

Table 1.2 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
Concord(e) Supersonic Aeroplane, UK, France	1,100
Troy and Greenfield Railroad, USA	900
Montreal Summer Olympics, Canada	720
Excalibur Smart Projectile, USA, Sweden	650
Canadian Firearms Registry, Canada	590
Medicare Transaction System, USA	560
National Health Service IT System, UK	550
Bank of Norway Headquarters, Norway	440
Lake Placid Winter Olympics, USA	320
Furka Base Tunnel, Switzerland	300
Verrazano Narrow 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
Shinkansen Joetsu 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, Netherlands	60
Great Belt East Bridge, Denmark	50

This is not to say that megaprojects do not exist that were built on budget and on time and delivered the promised benefits (Chapter 12, Gil; Chapter 14, Davies et al.). The Bilbao redevelopment project, with the Guggenheim Museum Bilbao, is an example of that rare breed of project (Chapter 22, del Cerro Santamaria). Similarly, recent metro extensions in Madrid were built on time and to budget (Flyvbjerg 2005), as were a number of industrial megaprojects (Merrow 2011). It is particularly important to study such projects to understand the causes of success and test whether success may be replicated elsewhere. It is far easier, however, to produce long lists of projects that have failed in terms of cost overruns and benefit shortfalls than it is to produce lists of projects that have succeeded. To illustrate, as part of ongoing research on success in megaproject management, the present author and his colleagues are trying to establish a sample of successful projects large enough to allow statistically valid answers. But so far they have failed. Why? Because success is so rare in megaproject management that at present, it can be studied only as small-sample research, whereas failure may be studied with large, reliable samples of projects.

Success in megaproject management is typically defined as projects delivering the promised benefits on budget and on time. If, as the evidence indicates, approximately 1–2 out of ten megaprojects are on budget, 1–2 out of ten are on schedule, and 1–2 out of ten are on benefits, then approximately 1–8 in a thousand projects is a success, defined as on target for all three. Even if the numbers were wrong by a large margin the success rate would still be dismal. This serves to illustrate what may be called the "iron law of megaprojects:" *Over budget, over time, under benefits, over and over again* (Flyvbjerg 2011). Best practice is an outlier, and average practice a disaster, in this interesting and very costly area of management.

1.6 The Megaprojects Paradox

This analysis leaves us with a genuine paradox: the so-called megaprojects paradox, first identified by Flyvbjerg et al. (2003: 1–10). On one side of the paradox, megaprojects as a delivery model for public and private ventures have never been more in demand, and the size and frequency of megaprojects have never been larger. On the other side, performance in megaproject management is strikingly poor and has not improved for the 90-year period for which comparable data are available, when measured in terms of cost overruns, schedule delays, and benefit shortfalls.

Today, megaproject planners and managers are stuck in this paradox because their main delivery method is what has been called the "break–fix model" for megaproject management.[6] Generally, megaproject managers—and their organizations—do not know how to deliver successful megaprojects, or do not have the incentives to do so. Therefore megaprojects tend to "break" sooner or later—for instance, when reality catches up with optimistic, or manipulated, estimates of schedule, costs, or benefits; and delays, cost overruns, and so on, follow. Projects are then often paused and reorganized—sometimes also refinanced—in an attempt to "fix" problems and deliver some version of the initially planned project with a semblance of success. Typically, lock-in and escalation make it impossible to drop projects altogether, which is why megaprojects have been called the "Vietnams" of policy and management: "easy to begin and difficult and expensive to stop" (White 2012; also Cantarelli et al. 2010; Ross and Staw 1993; Drummond 1998). The "fix" often takes place at great and unexpected cost to those stakeholders who were not in the know of what was going on and were unable to or lacked the foresight to pull out before the break.[7]

The break–fix model is wasteful and leads to a misallocation of resources, in both organizations and society, for the simple reason that under this model decisions to go ahead with projects are based on misinformation more than on information, with misinformation caused by a lack of realism at the outset. The degree of misinformation varies significantly from project to project, as seen by the large standard deviations that apply to cost overruns and benefit shortfalls documented by Flyvbjerg et al. (2002, 2005). We may therefore *not* assume, as is often done, that on average all projects are misrepresented by approximately the same degree and that, therefore, we are still building the best projects, even if they are not as good as they appear on paper. The truth is, we do not know, and often projects turn out to bring a net loss, instead of a gain, to the government or company that promoted them. The root cure to the break–fix model is to get projects right from the outset so that they do not break, through proper front-end management, and then have competent teams deliver a realistic front end (Chapter 18, Volden and Samset; Williams and Samset 2010). But megaproject managers must also know how to fix projects once they break, for the simple reason that so many break. The present book deals with both types of situation: (i) getting projects right from the start, and (ii) fixing projects that break.

1.7 Challenges, Causes, Cures

The chapters in the book have been selected to give readers a thorough, research-based understanding of (i) the *challenges* in megaproject management, (ii) the root *causes* of those challenges, and (iii) *cures* that may help meet the challenges. The book is thus systematically focused on the *what*, the *why*, and the *how* of megaproject management. In addition, it contains a set of case studies to exemplify general points.

First, as regards the *what* of megaproject management—the *challenges*—Lenfle and Loch (Chapter 2) and Siemiatycki (Chapter 3) present the historical overview. Ansar et al. (Chapter 4) focus on the basic challenge of scale and attempt to theorize scale in terms of fragility. Levitt and Scott (Chapter 5) deal with institutional challenges, especially as these pertain to global megaprojects; that is, projects that span activities in multiple countries, as is increasingly common for megaprojects. van Wee and Priemus (Chapter 6) spell out an important but often overlooked aspect of megaproject management: namely, the ethical and political issues involved; what is megaproject ethics, they ask? Finally, Ren (Chapter 7) poses a truly sobering question of current debt-financed megaproject investments in China: "Is this the biggest infrastructure bubble in the history of humankind?"

Second, for the *why* of megaproject management—the *causes*—Flyvbjerg (Chapter 8) explores a recent claim made by Cass Sunstein, professor at Harvard, that behavioral economics was pioneered by early research on large projects and that this research accounts well for behavior with megaproject planners and managers. Drummond (Chapter 9) updates and appraises key theories on escalation of commitment and lock-in, as they pertain to megaprojects. Miller et al. (Chapter 10) explain megaproject management in terms of games of innovation, and they explicate how the game is best played. Clegg et al. (Chapter 11) present an overview of how scholars and practitioners make sense of megaprojects and megaproject management, and how power is related to such sensemaking. Gil (Chapter 12) introduces a new collective-action perspective on the planning of megaprojects with a focus on dispute resolution, central to any megaproject. Baade and Matheson (Chapter 13) spell out the drivers of megaevents in emerging economies—an issue of growing importance as megaevents and other types of megaprojects have shifted in increasing numbers from developed to emerging economies, with the major part of investments now happening in the latter.

Third, concerning the *how* of megaproject management—the *cures*—Davies et al. (Chapter 14) describe a new delivery model for megaprojects aimed at securing innovation and flexibility in projects, and they illustrate how the model worked for three UK megaprojects. Winch (Chapter 15), drawing on developments in strategic management research, broadens the notion of stakeholder management to better take into account pressing issues of future generations and the natural environment. Hodge and Greve (Chapter 16) ask and answer the question of how well privatization works as a cure to the challenges of megaproject delivery. Vickerman (Chapter 17) identifies as dubious the common claim that the wider benefits of megaprojects are large and will often justify projects, even when direct benefits do not. Volden and Samset (Chapter 18) describe how Norway implemented a quality assurance program for megaprojects and how this has improved outcomes. Based on a lifetime of research, Scudder (Chapter 19) closes this part of the book by synoptically asking and answering the following question of the perhaps ultimate megaproject, the megadam: "Does the good megadam exist, all things considered?"

Fourth, and finally, Holzmann et al. (Chapter 20) launch the *case studies* with an in-depth inquiry into how the team on Boeing's 787 cracked the code of innovation in megaproject delivery—something high on the agenda for most megaprojects, irrespective of type. Davies (Chapter 21) spells out the lessons learned from the London 2012 Olympic Games in terms of systems integration—again a general concern in most megaprojects. del Cerro Santamaria (Chapter 22) updates and sets straight the record for perhaps the most iconic urban megaproject of the past generation, the $1.5-billion Strategic Plan for the Revitalization of Metropolitan Bilbao, spearheaded by what Philip Johnson, the godfather of architecture, called "the greatest building of our time:" Frank Gehry's Guggenheim Museum Bilbao. Chung (Chapter 23) navigates the maze of Australia's slightly dodgy experience with public–private partnerships in the provision of motorways, and identifies the challenges and opportunities for going forward. van der Westhuizen (Chapter 24) tells the story of megaprojects as mythical political symbols, focusing on Africa's first high-speed railway, the Gautrain, which was initially packaged with South Africa's bid to host the 2010 Soccer World Cup, another first for Africa. Lastly, Ahlers et al. (Chapter 25) study the Aswan High Dam on the Nile and the Nam Theun 2 on the Mekong to illustrate how dam development has changed recently to a situation where political power is more diffuse and where basic transparency and citizens' rights are therefore more difficult to secure; the authors suggest "dam democracy" as an organizing principle for addressing these issues.

In sum, the chapters for this book were selected to be strong on theory and to contain high-quality data, as an antidote to the weak theory and idiosyncratic data that characterize much scholarship in megaproject management (Flyvbjerg 2011). Strong theory is here understood as ideas with a high degree of explanatory power for phenomena in megaproject management. Good data are valid and reliable information that allows systematic comparison of important variables across projects, studies, geographies, and time, or make possible high-quality in-depth case studies. The focus on strong theory and good data is intended to help bring the field forward academically and professionally. As a further criterion, chapters were selected that are relevant not only to developed nations, but also to emerging economies, because at present the main part of investments in megaprojects is taking place here. Finally, chapters providing an historical overview of the field and good case studies have been included. The intention has been to produce a well-rounded book that is a must-read for anyone embarking on study, research, or practice in megaproject management, or who is impacted by megaprojects and wants to understand them better.

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Bent Flyvbjerg
Jericho, Oxford
July 2016

Notes

1. See more at <http://www.oxfordhandbooks.com>.
2. "Megaprojects" are usually measured in billions of dollars; "major projects" in hundreds of millions; and "projects" in millions or tens of millions. Megaprojects are sometimes also called "major programs."
3. Google search, 17 January 2017.
4. "Uniqueness bias" is here defined as the tendency of planners and managers to see their projects as singular. This particular bias stems from the fact that new projects often use non-standard technologies and designs, leading managers to think their project is more different from other projects than it actually is. Uniqueness bias impedes managers' learning, because they think they have nothing to learn from other projects as their own project is unique. This lack of learning may explain why managers who see their projects as unique perform significantly worse than other managers (Budzier and Flyvbjerg 2013). Project managers who think their project is unique are therefore a liability for their project and organization. For megaprojects this would be a megaliability.
5. Quoted from "Under Water Over Budget," *The Economist*, 7 October 1989, 37–8.
6. The author owes the term "break–fix model" to Dr Patrick O'Connell, former Practitioner Director at the BT Centre for Major Programme Management, Saïd Business School, University of Oxford.
7. For a rare look behind the scenes of a break–fix project—to see in real time how a break happens and a fix is attempted—see Flyvbjerg et al. (2014), about Hong Kong's XRL high-speed rail line to mainland China, which broke in 2014, midway through construction.

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PART I

CHALLENGES

CHAPTER 2

HAS MEGAPROJECT MANAGEMENT LOST ITS WAY?

Lessons from History

SYLVAIN LENFLE AND CHRISTOPH LOCH

The performance track record of megaprojects is dismal, even though the basic ingredients of successful large project management are not new. Put simply, the trick is to combine *uncertainty* in dealing with the difficulties of long time horizons and non-standard technologies with *stakeholder complexity* as expressed through the involvement of multiple powerful interested parties (Flyvbjerg and Cowi 2004). This challenge was conquered in the successful creation of the atomic bomb in the 1940s; but seventy years on, some of the lessons of the Manhattan Project are not being heeded, and modern megaprojects are the poorer because of it.

Take the nuclear reactor industry, a poster child for delays and budget overruns. The current generation II EPR reactors were announced as the future in 2003, and construction began on the first project in Finland in 2005 with plans to launch operation in 2009. But this project will (as of the status in August 2015) not start operating before 2018 and has already incurred a cost escalation from €3.3 billion to €8.5 billion (World Nuclear Association 2015). Another project using the EPR technology in Flamanville in France is now expected to take more than double the original timeframe and cost €9 billion rather than the initial estimate of €3.3 billion (*Le Monde*, 21 April 2015). The Hinkley Point C project in the United Kingdom is too early in its construction to show large overruns, but to reflect high risks, there are hefty price guarantees built into its building contract (Taylor 2016: ch. 12).

Nuclear power is not alone. Studies show that 90% of major projects are over budget, with overruns of above 50% being common (Flyvbjerg 2011). A country-specific study in Germany found that among 170 megaprojects, the average budget overrun was 73% (Kostka 2015). One study calls big cost overruns the "iron law of megaprojects" (Flyvbjerg 2014).

This chapter illustrates that it is possible to identify a few core management shortcomings that have significantly contributed to such systemic-like failures. We then show that knowledge of how to address these shortcomings existed and was partly applied as early as during the World War II. Thirdly, we will use this review of past knowledge in order to sketch some recommendations for managerial measures that might help improve performance of megaproject management today.

2.1 Three Common Causes of Megaproject Failures

When we describe the spectacular failures of large projects over the last decades, three overarching themes arise.

2.1.1 Underestimation of, or Refusal to Acknowledge, Uncertainty

Megaprojects are often started on the assumption that with enough planning, the design and project plan can be firmly designed at the beginning. But over long timeframes, with non-standard technology and multiple interested parties, it is impossible to plan for everything—and parties then slip into a damaging fight for control that results in multiple redesigns and additional costs.

A case in point is the Circored project, a pioneering iron ore reduction facility to produce pure iron briquettes, undertaken in Trinidad (Loch and Terwiesch 2002). The project began in 1995 with a target start of production in 1999, owned and run by the iron-ore company Cleveland Cliffs, using a new technology that Lurgi AG had developed and tested in a small prototype. An intensive risk analysis suggested that all problems could be anticipated and managed, but many unforeseen problems occurred in the scale-up, delaying the project by two years. Although the project ultimately succeeded technically, the delay made the facility vulnerable to the commodity price meltdown of 2002 and thus unprofitable. Ultimately, Cleveland Cliffs wrote off the plant and sold it at a steep discount to Mittal.

A key reason for the failure is that while Lurgi understood its technology's immaturity and technical risks, the plant owner rejected a longer testing phase on grounds that risks could be contained through proper planning and analysis. So ensuing problems had to be dealt with reactively, costing more in time and money than if properly addressed to begin with.

2.1.2 Stakeholder Neglect or Mismanagement

Megaprojects normally require coalitions of active partners in addition to the support or at least passive tolerance of external stakeholders who do not participate directly. Peril inevitably results when stakeholders are ignored, or when a false agreement is finessed, causing conflicts to fester, hidden behind wooly political statements.

A famous example is the Eurotunnel project (Bensen et al. 1989a and b), which between 1987 and 1994 dug a 50-km twin tunnel under the English Channel, through which passenger and freight trains now pass between Calais and Dover. The initial project had a seven-year duration and a (1987) budget of £4.8 billion, but ran over by 29% in schedule (after the original opening target of June 1993, freight operations started in May 1994, but full operations were not achieved until December 1994), and ran over budget by 65%, for a total cost of £8 billion. Also, some initial specifications were not achieved, with trains running through the tunnel at 80 km/h compared with the original target of 160 km/h—thus extending travel time and reducing tunnel capacity. But most importantly, the operator, Eurotunnel plc, came out of the project so debt-burdened that it could not turn a profit, and shareholders lost their investment twice (Garg et al. 2008), until finally the banks forgave a significant percentage of the debt in 2013.

The Eurotunnel troubles were *not* rooted in uncertainty: although some new tunneling machinery was used, related problems were quickly handled, and initial projections of revenues and operating profits turned out to be fairly close.

Instead, the root cause for Eurotunnel's woes was in the fraught relationships among the stakeholders: the construction consortium and the later operator Eurotunnel were in constant conflict and embroiled in lawsuits; the banks managed to transfer all risks, including inflation, to Eurotunnel, which resulted in a three-month work hold-up and an inflated debt burden.

Stakeholder conflicts are a major source of project problems and are especially dangerous for megaprojects, which by their very nature involve many parties with the power to exert influence. Whenever a party is ignored, or when an agreement forces one party into agreement or superficially glosses over differences in views or interests, then these agreements probably break apart when changes disrupt the equilibrium—at which point the parties then no longer collaborate but work against one another (Loch et al. 2015).

2.1.3 Inflexible Contractor Management (Prominently, Awarding Work to the Lowest Bidder)

Many parties have to collaborate in order to accomplish megaprojects owing to their sheer size and variety of expertise required. The well-known practice of "bid low and sue later" is caused by project owners awarding contracts on the basis of the lowest bid price, forcing contractors to bid aggressively and then work inflexibly—asking for more compensation with every change in the project.

This was already observed thirty years ago (McDonald and Evans 1998), and is still alive and well—and criticized by a German government commission that examined practices in large public works projects (Kammholz 2015). A globally visible specific example is in the $5.25-billion megaproject for the expansion of the Panama Canal, which invited bids in 2009 and was scheduled to open in 2014. A Spanish-led consortium of construction firms won the $3.2-billion bid for the locks of the fifty-mile waterway, underbidding a US-led rival consortium by $1 billion. But in 2014 the consortium demanded a $1.6-billion compensation from the Panama Canal Authority (PCA), the project owner, citing “breaches of contract” (for example, claiming they were misled about geological ground conditions). The dispute has already delayed the project to mid-2015. However, concerns were voiced right at the outset that the bid was too low, and that a cost increase would be required at some point (Kriel and Dowsett 2014). Although the PCA defends the original bid as reasonable, experts openly discuss the aggressive underbidding strategy used (*The Economist* 2014).

2.1.4 Interactions Among the Themes

These three root causes of problems are even more difficult to address because they strongly interact. For example, stakeholders in the Eurotunnel project had differing interests such as the short-term view of the constructor versus the long-term operator’s view. In an atmosphere of mutual distrust, even moderate uncertainties are difficult to address, leading to disputes (such as over cost overruns) and even further distrust. As a result, collaboration becomes even harder.

Yet although these challenges are difficult to address, there are potential solutions that have been ignored. Relevant knowledge has been available for seven decades, but much of this knowledge has been disregarded and not used effectively in the project community—as we describe next.

2.2 What Project Management Already Knew in the 1940s

The irony is that, historically, there were projects where these three problems were in fact overcome. This is particularly true of the World War II and large post-war US military and space projects which, interestingly, are the roots of contemporary project management. Indeed, the Manhattan, Atlas, Polaris, and Apollo projects, to name the most famous ones, were managed very successfully, and on schedule. It is therefore interesting to draw lessons from these cases. At the conceptual level, these projects did two crucial things right.

First, on the organizational level, they created almost from scratch a dedicated organization to overcome the traditional bureaucratic fights that plagued major R&D projects. The development of Intercontinental Ballistic Missiles (ICBM) within the US Air Force and the US Navy is typical of this strategy. Consider briefly the Polaris case (Sapolsky 2003). The problem was to coordinate and integrate the functionally defined branches or bureaus and the dozens of firms involved. Moreover, as a new technology, ballistic missiles did not fit easily into the existing weapons acquisition structures: it was neither a bomber, nor a bomb, nor a guided missile. To overcome this problem, the Navy created the Special Project Office (SPO)—a new body that had complete autonomy and power to manage the Polaris project. It was supervised by a brilliant and powerful project manager, Admiral William F. Raborn, who infused a sense of dedication and urgency into the entire team. He said: "Our religion was to build Polaris" (Spinardi 1994: 35). The creation of this structure constitutes unquestionably one of the key success factors of the Polaris project (Sapolsky 1972). And we find a similar logic, a dedicated organization led by a brilliant project manager, in all the aforementioned projects (the Manhattan Engineer District and L. Groves, the Western Development Division of the USAF and B. Schriever, the Office of Manned Space Flight and S. Phillips). Therefore, the success of these projects rested on "doing what it took" with almost unlimited project management power, supported by almost complete autonomy to take the right actions in the interest of achieving the goals.

Second, concerning the management of uncertainty, these PMs developed brilliant insights. They understood, right from the outset, that one does not know what one does not know. This cannot be more clearly stated than by General Groves when he stated that, given the huge unforeseeable uncertainties of the design of the atomic bomb, they were "proceeding in the dark" (Groves 1962: 40) and, therefore "had to abandon completely all normal orderly procedures" (72).

What is fascinating is that they drew the right managerial conclusions: they combined experimentation (for example, in the form of pilots), parallel pursuit of alternatives, and dedicated (possibly costly) actions to gather information as part of the core project activities. The Manhattan Project forcefully demonstrates the relevance of this approach: acknowledging that it was impossible to define, at the outset, the right design of an atomic bomb, Groves and the steering committee decided to simultaneously explore different technical solutions both for the production of fissionable materials and for the design of the bomb. This explains why the two bombs dropped on Japan had completely different designs, and also how they succeeded in such a short time to overcome the tremendous scientific and engineering challenges (Lenfle 2011). This strategy was transferred directly to the ICBM Atlas project (and others) through discussions between Groves, Oppenheimer, and B. Schriever, chief of the Western Development Division of the USAF (Hughes 1998).

It is sobering for project management how these lessons have been lost in the course of the institutionalization of the discipline. Indeed, the principles of uncertainty management were theoretically well understood in the 1950s, especially the need for experimentation and adjustment, and the advantage of starting multiple parallel trials on subprojects in order to assure one successful outcome (Alchian and Kessel 1954; Arrow 1955; Klein and Meckling 1958). However, these principles had completely disappeared from PM textbooks and have only recently been rediscovered (from the view of multiple disciplines, for example, Leonard-Barton 1995; Loch et al. 2006). Lenfle and Loch (2010) show how flexible approaches to uncertainty were abandoned in favor of a more control-oriented view of PM as the accomplishment of a clearly defined goal through a phased/stage-gate logic.

This process unfolded in three dimensions (Lenfle and Loch 2010):

1. On the political side, the deployment of ballistic missiles completely changed the context. The fear of a "missile gap" disappeared, and the sense of utmost urgency of the military megaprojects faded away. This led to an important reorganization within the DoD in the form of the *Defense Reorganization Act* of 1958, which greatly increased the power of the Secretary of Defense over the armed services. It gave him the authority to "transfer, reassign, abolish, or consolidate" service functions, and control over the budget. This paved the way for the "McNamara revolution." Coming from the Ford Motor Company, Robert McNamara, named Secretary of Defense in 1961, started a complete reorganization of the planning process in the DoD. His objective was to consolidate planning and budgeting, which hitherto had been two separate processes. He pursued his objective with the implementation of the famous Program Planning and Budgeting System (PPBS). This process was antipodean with the logic of the early missile projects and prompted a complete reversal in project management. Indeed, it emphasized the complete definition of the system *before* its development in order to limit uncertainty and institutionalize a phased approach. This *de facto* eliminated parallel trials and concurrency. Therefore, the phased-planning approach (now called Stage-Gate) became the project management model of the DoD and the newly formed NASA (Johnson 2000). This was enforced by the diffusion of managerial tools such as PERT. In particular, a *NASA/DoD PERT/Cost Guide* was issued in 1962 and became part of the bidding process of both administrations, transforming these tools into *de facto* standards for project management. This limited the scope of project management for the ensuing decades. From now on, strategy was centralized at the DoD, and Project Management's role was to execute given missions.
2. This shift had a theoretical counterpart. Indeed, the McNamara revolution was theoretically grounded in RAND thinking and its faith in rational decision making.[1] This view was clearly expressed by Charles Hitch, an eminent RAND member who later became comptroller of the Department of Defense under McNamara. In 1960 he published *The Economics of Defense in the Nuclear Age*, which introduced a broad audience to a view of defense as an economic problem of resource allocation to achieve a desired objective. This view had major consequences for project management: the focus gradually changed from the "performance at all costs" attitude of the first missiles projects to one of optimizing the cost/performance ratio.

This new logic is clearly visible in the early literature on project management. For example, *Systems Analysis and Project Management* (1968) by Cleland and King became a classic. The book is typical of the phased logic. It consists of two parts that corresponded to the two key project phases. The first advocated the power of systems analysis to analyze complex strategic issues and define project missions. The second part dealt with project execution and emphasized the need to create a specific project organization to integrate stakeholder contributions, along with project planning and control using formal methods. The result of all of these events was that by the early 1970s the phased approach had become "natural."

3. The last stage of this standardization process was the creation, in 1969, of a professional organization: the US Project Management Institute. Indeed, the years following the success of Polaris saw a plethora of publications and an intense promotion of the PERT/CPM method by numerous consulting firms (Vaszonyi 1970). The planning method was viewed as synonymous with success in the management of large projects. The idea of a professional association arose in this context within the tight-knit community of PERT and CPM users (R. Archibald, E. Benett, J. Snyder, N. Engman, J. Gordon Davis, and S. Gallagher). Since all its founders were project control experts, it was natural for the PMI to focus on control tools, such as PERT/ CPM. Therefore, for the next two decades, "modern project management" became equated with PERT/CPM after Polaris and the MacNamara revolution (Snyder 1987).

This, as the reader will recognize, provides the basic principles of the dominant model of project management today: the stage-gate process. The problem is that this rational view of project management oversimplifies the processes at stake, particularly for innovative projects and for megaprojects with their inbuilt unforeseeability (because of long timeframes and stakeholder complexity). Moreover, this leads, as argued by Lenfle and Loch, to misinterpretations of the success factors of these projects. For example, Apollo is remembered in the project literature for the setting up of a complex project management system organized around a phased approach (Seamans 2005; Johnson 2002). While this unquestionably contributed to getting back on track during the project crisis of 1962–63, this narrow view neglects the upstream exploratory work and the fact that the phased approach was implemented quite late in the project. However, the fact is that this control-oriented approach of project management remains dominant today.

2.3 The Limitations of the Breakthrough Project Management Styles of the 1950s

Based on the previous discussion, we might ask the question whether the issue is to "get some of the capability of the 1940s and 1950s back." But this, we think, would be too simple. Indeed, these projects unfolded in a very specific context and, therefore, were not exposed to the full spectrum of complications that face the megaprojects of today. One has to remember that, for all these projects, the context was the highest level of national urgency either because of World War II (Manhattan) or the Cold War with the USSR (Atlas, Polaris, and Apollo). This had two major consequences.

First, the project goals reflected the military nature of the missions and were, in a sense, "simple" (although technically impressive): build a nuclear bomb, build a missile that can hit a small target from a long distance, start the missile from a submarine, or go to the moon.[2] These do not reflect the goal complexity of projects that, today, inevitably have a societal component.

Second, the Cold War and the competition with the Soviets led to the suppression of any debate around the projects. It is useful here to remember John F. Kennedy's address to the Congress that formally launched the Moon project:

> If we are to win the battle that is going on around the world between freedom and tyranny, if we are to win the battle for men's minds, the dramatic achievements in space which occurred in recent weeks should have made clear to us all, as did the Sputnik in 1957, the impact of this adventure on the minds of men everywhere who are attempting to make a determination of which road they should take. (…) We go into space because whatever mankind must undertake, free men must fully share. (…) I believe this Nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish. (Special Message to the Congress on Urgent National Needs, 25 May 1961)

Indeed, if the stakes were "the battle between freedom and tyranny," there could be no debates around the project.[3] In other words, if we rely on contemporary concepts, stakeholder disagreements were absent or small. There were no parties that stopped support, or protesters that blocked further work, because they no longer agreed with changed outcomes, or external groups that demanded transparency and accountability.

This was also true for supplier management. These project teams had huge power over their suppliers—again, these were military projects where suppliers were paid well but had to unquestioningly carry out orders. In fact, the entire organization was designed to avoid politics. As demonstrated by Hughes (1998) for Atlas, and Sapolsky (1972) for Polaris, the main goal of the creation of the WDD and the SPO was explicitly to avoid the bureaucratic fights and politicking that, traditionally, plagued large R&D projects. They were, in a sense, "closed" projects (Edwards 1996; Hughes 1998). Politics was reduced to the army and the government. There could be debates, but no protest outside likely to stop the project (Beard 1976). It was possible for Admiral Raborn to "build a fence to keep the rest of the Navy off of us" (Sapolsky 1972: 124) and to "engineer the politics of the program so as to provide resources without interference" (Spinardi 1994: 35–6). Therefore, the question of stakeholder management was literally out of the scope.

This very specific context disappeared with the end of the Cold War and the emergence of a networked world—it is no longer the case in megaprojects today. Now the challenge is to manage megaprojects in an "open" context in which no project team can hope to keep the outside world behind a fence. In this perspective, Hughes (1998) brilliantly demonstrates that the "system engineering" methods developed for military projects failed when confronted with civil megaprojects such as the famous Boston Central Artery Tunnel. Here, the challenge was to deal with the messy complexity of multiple stakeholders, each with different objectives and constraints. F. Salvucci, the Boston CA/T key figure, had to patiently negotiate his way through the maze of the Boston area, discussing with engineers, community groups, the City, the State of Massachussets, and so on, around to-be-defined criteria, such as the design of a bridge. Therefore, as argued by Lundin et al. (2015: 201–2), "The traditional view of the 'project client' as the single focal interlocutor of the project vanishes, giving place to a complex fuzzy system of diversified actors that has to be 'managed' in novel sophisticated governance and communication processes." The problem is all the more important because, they argue, there is an ever-growing demand of accountability for public and private megaprojects. General Groves never had to deal with this situation.

In other words, we cannot simply go back to the heyday of 1950s project management—what worked brilliantly then would be insufficient today. And yet, it is still worthwhile to repeat the lessons on uncertainty management from the 1950s, as some of the recent failed megaprojects simply violated what is known about uncertainty management. Moreover, knowledge on all three key drivers of megaproject failure has slowly accumulated over the last fifty years, not only on uncertainty management but also on stakeholder and contractor management. We will review the key lessons of this knowledge history in Section 2.4.

2.4 Lessons and Recommendations

2.4.1 Managing Uncertainty

Building on the work from the 1940s described earlier, project management theory has, since the stage-gate process became dominant, been able to articulate that many projects are characterized by variation (many small influences causing a possible range of duration and costs on a particular activity), which can be addressed by buffers, and foreseeable uncertainty or risk (identifiable and understood influences that the project team cannot be sure will occur, so different outcomes are possible), which can be addressed by planned and "programmed" risk management that "triggers" contingent actions depending on which risks occur (De Meyer et al. 2002). However, megaprojects suffer also from unforeseen uncertainty, which cannot be identified during project planning. The team either is unaware of the event's possibility or cannot create the contingencies. Unforeseeable uncertainty may be caused by large "unthinkable" events, or by many influences (including stakeholder actions) that interact through complexity. Unforeseeable uncertainty requires more flexible and "emergent" approaches than smaller uncertainty levels do (and than the stage-gate process has allowed for).

Still, the presence of unforeseeable uncertainty can be diagnosed. For example, discovery-driven planning (McGrath and MacMillan 1995, 2000) proposes to explicitly acknowledge that unknown unknowns exist and to uncover them with analyses such as assumptions checklists. Similarly, Loch et al. (2008) illustrated with the example of a start-up venture project, how the presence of unknown influences can be diagnosed by systematically probing for knowledge gaps in the project, building intuition about areas where unknown events may be looming. Two fundamental approaches exist for this level of unforeseeable uncertainty: trial-and-error learning and selectionism (Leonard-Barton 1995; Pich et al. 2002; Loch et al. 2006).

Under *trial-and-error learning*, the team starts moving toward one outcome (the best it can identify), but is prepared to repeatedly and fundamentally change both the outcome and the course of action as new information becomes available. Exploratory experiments, aimed at gaining information without necessarily contributing "progress," are an important part of this approach; failure of such experiments is a source of learning rather than a mistake. It is therefore important to track the learning and reduction in knowledge gaps rather than tracking only the progress toward a target. Well-known examples are pharmaceutical development projects, in which promising indications often emerge during large scale trials via unexpected (positive) side effects.

Alternatively, the team might choose to "hedge" and opt for *selectionism*, or pursuing multiple approaches in parallel, observing what works and what does not work (without necessarily having a full explanation why) and choosing the best approach *ex post facto*. Examples of this approach abound, including Microsoft's pursuit of several operating systems during the 1980s (Beinhocker 1999), or "product churning" by the Japanese consumer electronics companies in the early 1990s (Stalk and Webber 1993).

In a large-scale empirical study of sixty-five new venture projects, Sommer et al. (2009) showed that the best combination of learning and selectionism, as measured by their effect on project success, depends on the level of unforeseeable uncertainty in the project and the complexity of the project (Figure 2.1). When both uncertainty and complexity are low (lower left quadrant), planning and standard risk management are up to the task and the most efficient. When unforeseeable uncertainty looms large, be flexible and apply trial and error. When complexity is high, use parallel trials and narrow the field down to the best as soon as possible. The hardest situation is in the upper right quadrant, which is where megaprojects usually find themselves and where unforeseeable uncertainty and project complexity combine. It turned out that the highest success level was associated with parallel trials if they could be kept alive until uncertainty had been reduced to the point that all important risks were known. Otherwise, trial and error performed better. Of course, in any large project, trial and error and selectionism can be combined and applied differently across subprojects.

The largest challenge lies in the managerial structures and control-mindedness in large corporations, partially prompted by the stage-gate process revolution of the 1960s,

Unforeseeable uncertainty	Complexity: Low	Complexity: High
High	**Learning** Flexibility to fundamentally re-define business plan and venture model	**Selectionism** Selectionism is most effective *if* choice of best trial can be deferred until unk unks have emerged (true market response is known)
Low	**Planning** • Execute plan toward target • Risk identification and risk management • Learning and updating	**Selectionism** • Plan as much as possible • Try out several alternative solutions and choose the best as soon as possible

FIGURE 2.1 When to choose trial-and-error-learning or selectionism.

(From Sommer et al. 2009.)

discussed previously. It makes it very difficult for managers in large organizations to take on risks. For example, one study on "breakthrough innovation" in large companies shows that they use a stage-gate-like approach to selecting and executing large innovations, which pushes managers to conservativism and early termination of risky projects (He 2015). Similarly, Sehti and Iqbal (2008) demonstrated that the stage-gate process leads to project inflexibility, which, for innovative projects, is synonymous with failure. Even more fundamentally, the stage-gate process has shaped an "aesthetic" of eliminating uncertainty and experimentation through rigid up-front planning and control. For example, a study of relationships between startups and investors found that investors reacted with "punishment" (that is, by enforcing business reviews) to evidence of parallel trials and (to a lesser degree) trial-and-error iterations (Loch et al. 2011). Managers are, in principle, fully capable of intelligently responding to unforeseeable uncertainty, as R&D management and many experienced project management organizations amply demonstrate. However, much education is needed in order to equip management in many (particularly public) organizations, investors, and critically, the public with the flexibility required to deal with uncertainty.

2.4.2 Stakeholder Management and Project Governance

No universally agreed "national agenda" exists any longer, based on which the brilliant projects in the 1950s could successfully proceed, because megaprojects touch on too many interests and agendas to still be able to be pushed by any central will. Consultation and involvement of powerful interested parties has become a must. On the other hand, political compromises do not make good bases for decisions, and muddled goals and inconsistent decisions based on fluctuating agreements destroy projects. How can these two imperatives be reconciled? This is a question of project governance.

Project teams execute, but the scope and strategic positioning of a project is set at the level of project governance, typically at the level of the "steering committee" (SC). Loch et al. (2015) examined effective and non-effective SC practices in seventeen complex and uncertain projects (innovation, as well as organizational change), and found that the SC is the place where representation of interests (including consultation) needs to be combined with the production of a shared project vision and the translation of this vision into operational plans—in order to effectively identify conflicts and solutions as the environment of the project changes.

Several specific principles arise from the study:

- Stakeholder representation: the SC needs to represent the most important and powerful parties that have an interest in the megaproject (such as government, suppliers, or customers). At the same time, the size of the SC must not grow too large (by allowing "anyone with interest to participate") because large groups become too difficult to manage and keep together.
- Goal agreement. The SC has the critical responsibility to articulate a project vision that is at least acceptable to all parties, and then translate it into operational goals and targets that expose key conflicts. "Motherhood and apple pie" goals regularly get thrown out during later operational phases when conflicts inevitably do occur. Only if the conflicts are negotiated at the outset (in a way that maintains a shared project vision) can the goals evolve and change in negotiated ways that allow maintaining a shared vision.
- Staying informed and renegotiating during crises. The SC must invest enough time and effort to understand the key issues of the project (insisting on translation of technical language and issues into the strategic policy or business language that is needed to maintain the strategic positioning of the project). The SC must also invest the time and effort to stay informed, so when changes and crises occur (both inevitable over the time horizon of megaprojects), project modifications can be renegotiated in ways so that the parties maintain their agreement/support. If a party feels excluded or taken advantage of, projects fail, but if the SC can successfully manage one crisis together, it becomes stronger in managing the next.
- Keeping the project team aligned. The SC must maintain a position of control, which means in this context, understanding the key issues rather than maintaining and enforcing ("come what may") an initial project plan. Trust needs to be built with the project team that bad news and changes are treated reasonably, demanding solutions and accountability, but not looking for scapegoats to punish—otherwise, information about the true status of the project will not be forthcoming. This is necessary because changes *will* happen in a megaproject, and the SC needs to set up itself, as well as its project team, to be able to address these changes in ways that do not lead to the typical symptoms of megaproject disasters—such as mission creep, late mission changes because of political maneuvering, accumulated unaddressed problems, or the falling out with an important stakeholder.

Several key challenges exist that make these principles difficult to achieve. Interest conflicts and differences in thinking styles among stakeholders make the achievement of true alignment a long affair (leading to longer planning times) and consume significant managerial effort during a project. The temptations are ever present to not invest enough effort, or to exploit political circumstances of unbalanced power to one's own advantage.

This is also where the widely observed temptation of "low-balling early [on costs] and then present a fait-accompli to the stakeholders" (Flyvbjerg 2007) comes in. While this is certainly true in some cases, it is not inevitable. Evidence in Loch et al. (2015) suggests that if the SC represents stakeholders and seeks the dialog with them, and if it is sufficiently involved with the project team to be able to follow and evaluate progress, success overestimation can be avoided. Of course, this leaves out situations where a skeptical public (or political establishment) is simply not willing to accept a project under a realistic scenario, and the only way to get the project approved is by "lying" about it. But whoever engages in misrepresentations in order to get the project started ("they will learn and change their minds later") is running severe risks both for their own careers, as the project later runs into difficulties preprogrammed by the unrealistic initial estimates, and for the public, whose faith in project execution capabilities becomes undermined. Yes, it may be true that (for example) the Eurotunnel was a significant macro-economic success in hindsight, connecting London and Paris in ways that were previously unthinkable. But on the way there, many shareholders lost their money, and careers of good people involved were damaged, and so initial overpromising is perilous and not advisable, even if one might be able to construct a long-term justification for it.

2.4.3 Contractor Management

Contracts are core vehicles of governing partners and the subcontractors of pieces of work in projects, and they form a complex web of relationships in megaprojects. But contracts can handle only limited complexity (a contract can quickly run into thousands of pages, which means they become ineffective), and they are inflexible where flexibility is required to deal with the inevitable changes in megaprojects.

> A contract is a dangerous instrument and should always be approached with trepidation and caution … Theoretically, the aim of a written contract is to achieve certainty of obligation of each party, the avoidance of ambiguities, and such definiteness of understanding as to preclude ultimate controversy. In practice, construction contracts are generally formed not to definitely fix obligations, but to avoid obligations. (MacDonald and Evans 1998: 1–2)

Specifically, contracts cause the temptation to explore gaps in the understanding of the counterparty to create obligations that one can then exploit—a fallacious expectation because the other side usually finds a way to sooner or later stall in their turn or to retaliate (von Branconi and Loch 2004). The well-known temptation to "bid low and sue later" falls in this context, but it often leads to protracted business and legal battles, victimizing the project.

Much evidence has been accumulated that contracts need to be designed with *flexibility*, and they need to be complemented with *relationships*. A good example is the celebrated Heathrow Terminal 5 project, which applied an integrated approach that incorporated careful strategic governance (accomplishing system integration) within diligent process management that included supplier selection by track record (rather than the lowest bid price) and flexible contracts that rewarded problem solving (Davies et al. 2009b). The project owner BAA "changed the rules of the game" by creating a new type of agreement based on two fundamental principles: the client bears the risk and works collaboratively with contractors in integrated project teams. BAA had to take responsibility for risks and uncertainties, while creating an environment within which suppliers could find solutions. Suppliers were repaid all the costs on a cost-transparent "open book" basis and incentivized to improve their performance and innovate by bonuses for exceeding previously agreed "target costs" and completion dates. If the performance of a project exceeds target costs, the profits are shared among team members. This contractual approach was underpinned by routines to expose and manage risks rather than transfer or bury them, and offered incentives for innovation and problem solving (Davies et al. 2009a: 24–5).

The Heathrow Terminal 5 project addressed one fundamental problem with contracts: they cannot specify all desired outcomes beforehand in the complex and uncertain environment of a megaproject, and fixing any outcomes (no matter with how many "contingencies) opens up incentive conflicts when contractors either cannot deliver or can deliver in unforeseen ways. The cost-reimbursement contracts with "innovation bonuses" offered a way out of this dilemma. But it is possible to go even further in turning contracts from fixed outcome descriptions into vehicles for collaborative problem solving. One example for this is the OSA Alliance between Orange (France Telecom's mobile telephone arm) with its partners in managing roaming, the complicated agreements that allow regional telecom operators to provide service for a customer from other regions and be reimbursed by the telecom operator who has a contract with the customer and charges this customer for the roaming (Van Der Heyden et al. 2006). The "contract" that partner operators in the alliance signed up for did not specify any specific collaboration procedures or outcomes, but was nothing but a specification of a *collaborative problem solving procedure*: how would the group make decisions in setting up a technical system, or a customer agreement, or a revenue sharing when it arose. Decisions were indeed made by voting, with safeguards that neither the large operators (with a revenue majority) nor the many small operators (with most votes) could force through agreements. Each specific agreement itself (what would normally be seen as a contract) became a mere technical description. This structure of agreements allowed the partners to keep collaborating flexibly and robustly in an environment of changing technologies and regulatory regimes. (The regulatory bodies tightened rules on roaming which had become very profitable.) However, when we discuss such collaboration structures with project and program managers, they usually are very uncomfortable because it feels to them like a "loss of control." This is another example of the control "aesthetics" that the dominance of the stage-gate process has created in project management.

And yet there are again large challenges in adopting these new methods that would allow addressing the systematic problems that have plagued megaprojects. The temptation to use "market forces" to depress prices to contractors, using unbalanced power to get one's way (if only for a short period), is ever present. As a case in point, the Heathrow Terminal 5 owner BAA was acquired in 2006 and, "in a complete reversal of strategy (and to the surprise of many in the UK construction industry) decided to revert back to the traditional role of client as procurer rather than project manager, relying on 'risk-shifting contracts,' detailed up-front specifications and inflexible routines" (Davies et al. 2016).

Similarly, the authors have discussed the OSA "framework contract" approach with managers from many companies, and have witnessed directly how deeply threatening managers find such an approach—it feels to them as if they are giving away control over their own fate. Yet another cultural and "aesthetic" influence that has been connected to the stage-gate process, which adds a specific definition of "professional standards" to the earlier-mentioned short-term temptations in making it very difficult to make the new methods in megaproject management enter the mainstream.

2.5 Conclusion

System engineering and technical complexity are well understood, but uncertainty and stakeholder complexity are still the big challenges for megaprojects. Avenues have been identified to address these challenges that require behavioral changes: these include resisting the temptation to press one's own advantage with contractors; accepting some loss of predictability and control; patience in bringing the multiple sides to the table that are always present in megaprojects; and the discipline to maintain a common direction that allows progress-directed decision making rather than merely conflict-avoiding compromises. Many of these techniques will require companies to learn new and potentially daunting behavior; but in fact many of these managerial mechanisms are tried and true techniques that worked wonders for megaprojects a few generations ago and could help point the way to a brighter future for huge projects in the future.

Notes

1. McNamara's thinking was rooted in, and had a major impact on, "cold war rationality"—the belief that one could find the optimal solution beforehand. Here, the reader may refer to Erickson et al. (2013).
2. Apollo is an ambiguous case, since it was a civil project largely managed by the military after 1963.

3. On the Manhattan Project, there was no debate simply because it was a "black," completely secret, project. Even Harry Truman, Roosevelt's Vice-President, ignored the existence of the project until he became President in April 1945.

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CHAPTER 3

CYCLES IN MEGAPROJECT DEVELOPMENT

MATTI SIEMIATYCKI

3.1 Introduction

Infrastructure megaprojects are an enduring feature of human civilizations. Throughout the world, the landscape is marked by the remnants of historic efforts to undertake construction initiatives on a massive scale, from the Egyptian pyramids to the Roman aqueducts, roads, and Coliseum, to the Greek Parthenon. While large-scale public works have been significant throughout history, it was with industrialization that megaprojects rose to prominence, as a strategic investment in productive capital and as ideology (Lehrer and Laidley 2008: 788). Today there are many different types of megaprojects, including immense transportation, energy, healthcare, office tower, justice, telecommunications, cultural, and information technology infrastructures that support the functioning of a modern society.

Megaprojects are defined by their large scale in terms of costs, which can range from $100 million to upwards of $1 billion, depending on the context in which they are being developed. They can be funded, built, and operated by public-sector, as well as private-sector institutions or some combination of the two. Megaprojects are also defined in terms of the scale of planning and engineering complexity, the high level of public and political interest that they attract, and their outsized impact on the surrounding economic, social, and natural environment. Indeed, megaprojects are identified as the largest-scale infrastructure and development projects that a given society undertakes, which attract the greatest amount of public interest, and have the most significant impacts and externalities on their surrounding communities.

One of the more puzzling aspects of megaprojects is that they tend to follow distinctive cycles or waves of innovation. It is quite common for the development of a new technology or type of infrastructure megaproject in one place to spark a wave of similar projects developed in a variety of other locations, before they are usurped by a subsequent wave of development of a new technology in the same asset class or a different type of infrastructure altogether. Put differently, new technologies or types of megaprojects appear to diffuse across space, from the place where an innovative idea emerges, through to a surge in popularity in many locations, before it declines in popularity either because the project type does not function as expected, has fulfilled the required goal, or has been replaced by a new technology that provides even better benefits.

To date, such patterns have often been identified and dismissed as one-off fads capturing the economic imperative or cultural *zeitgeist* of a specific moment in time. For instance, the "Bilbao effect" is a popular term to explain how the development of a new Guggenheim Museum with an iconic building design in the northern Spanish city in the late 1990s sparked a tidal wave of museum and cultural-institution developments around the world. And scholars have identified a dramatic recent upswing in the development of urban tram or streetcar systems globally, which reimagine the streetcars that were pervasive in the early 1900s but removed from most city streets because they were seen as outdated and inefficient. Yet a closer examination across a wide range of infrastructure asset types and time periods suggests that there is consistency in this wave-like pattern in the development of specific types of infrastructure, over fairly brief time periods. New infrastructure megaproject technologies often rise on the ashes of previous innovations, are developed in punctuated bunches, and then recede in popularity as they are superseded by the next big thing.

How pervasive are these cycles or waves of megaproject development? How do we explain the transfer of megaproject ideas and development from place to place? And how can this insight inform the decisions of infrastructure project planners, policy makers, and investors? It is these questions that are the focus of this chapter. But first, it is necessary to briefly examine where new ideas come from, and how they spread over time.

3.2 Riding the Wave

The cyclical nature of innovation development and diffusion is a topic of great interest for academics, policy makers, business leaders, and the general public. Over the years, extensive attention has been paid to documenting cycles in the way that new fashion styles, music, technologies, public policies, business management strategy, and nutrition emerge and spread. An important insight into the cyclical development of innovative new ideas or products is that they tend to follow a consistent "natural history" through different identifiable stages—most succinctly defined by Best (2006: 21) as "emerging, surging, and purging." This natural history is characterized by a standard "S" innovation curve, which is often depicted in a wave-like pattern to denote that a new innovation typically builds on the foundation of a previous product or idea that has run its course or is being improved upon (Figure 3.1).

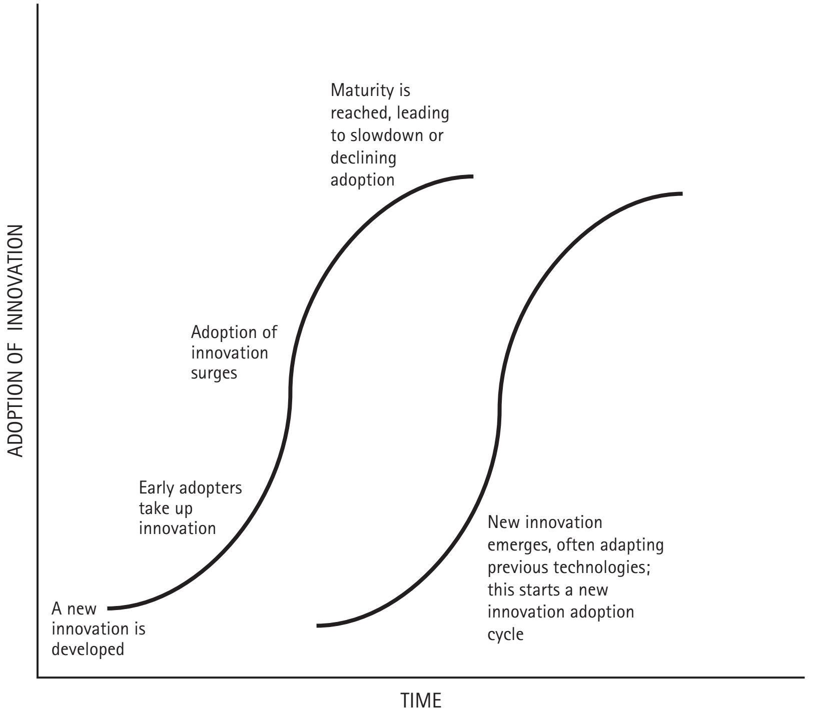

FIGURE 3.1 S-curve of innovation adoption.

To date, there has been limited examination of whether cycles of innovation diffusion may be an enduring part of the megaproject development process. However, when patterns of megaproject development are viewed at a global scale and tracked historically over time, it is clear that such dynamics are not just present, but are a driving force in determining which projects get built, where, and when. Table 3.1 provides an overview of seven types of megaproject dating back to the turn of the nineteenth century that have each displayed a similar emerge–surge–purge pattern in the way that they were developed, gained widespread adoption, and then subsequently declined in application. The following sections draw on illustrative examples of different types of megaproject to show the dynamics of infrastructure development cycles.

3.2.1 Riding the Wave, Again and Again

The century-long development of baseball stadiums in North America highlights the wave-like pattern of megaproject innovation. Baseball stadiums have been an enduring feature of the American landscape. However, the preferred design of these stadiums shifted abruptly when an innovator came along. As shown in Figure 3.2, baseball

Table 3.1 Selected waves of innovation in urban development, 1890–2007

Date	Description	Antecedents	Trendsetters	Surge	Decline
1890–1920	Electric tramways and streetcars	Animal-pulled omni-carts and trams in New York and New Orleans	Berlin electric demonstration tram in 1881	By the turn of the twentieth century, electrified trams were a common feature of the urban environment in cities on all six continents	Advances in bus and car technologies and spread of cities made trams less efficient, and they were removed from most cities by the 1960s
1900–1910	American city beautiful movement (redevelopment of city centers and parks using monumental designs)	Baron Haussmann's nineteenth-century redevelopment of Paris	Chicago 1893 "White City" Fair Grounds; Washington Mall redevelopment plan	City beautiful initiatives in Denver, New York, Seattle, Baltimore, Harrisburg, Philadelphia, and Chicago	Opposition to large expenses on urban aesthetics led to an increased emphasis on functionality of investments
1910–1935	Construction of British imperial capitals using city beautiful techniques	American city beautiful movement	Edwin Lutyens and Herbert Baker's design of New Delhi, begun in 1912	Imperial capitals initiatives in Lusaka, Salisbury (Harare), Nairobi, and Kampala	Beginning of decline of the British Empire, leading to independence following World War II
1935–1960	High-rise, single-use public housing megaprojects	Garden City; European Modernist movement, Le Corbusier	First Homes, New York City; Cabrini Green, Chicago; Boundary Estate, London; Stockholm Exhibition	St Louis, Chicago, Boston, Toronto, Birmingham, Paris, Stockholm, New Orleans, Glasgow, Sheffield, Atlanta, Detroit, Melbourne, and Sydney	Demolition of award-winning Pruitt-Igoe in St Louis sixteen years after it opened symbolized the failure of large housing projects; they have subsequently been demolished in many cities
1955–1970	Regional transportation planning and urban freeway construction	City beautiful movement, suburbanization following the end of World War II	Chicago Area Transport Study, 1955, which used regional traffic and economic modeling to emphasize new highway developments	Washington, Baltimore, Pittsburgh, Hartford, Philadelphia, San Francisco, Toronto, and Vancouver	High-profile protests opposing freeways in New York, led by urbanist Jane Jacobs, which spurred similar protests in other cities such as Toronto, San Francisco, and Vancouver

(*continued*)

Table 3.1 Continued

Date	Description	Antecedents	Trendsetters	Surge	Decline
1980–current	Light rail lines (adaptation of trams, either running on-street or on dedicated rights of way)	Nineteenth-century tramways; new urbanism emphasis on transit-oriented development	Rebranding and redesign of old trams as modern light rail in late 1970s: Gothenburg, San Francisco, Edmonton, and Portland	Between 1980 and 2000, more than sixty-five new light rail lines were constructed in cities around the world, and the construction of light rail lines continues to the present	n/a
1997–current	Iconic museums and cultural-led urban regeneration	City beautiful movement; Frank Lloyd Wright's 1959 Guggenheim Museum, New York	Bilbao Guggenheim Museum, designed by Frank Gehry	New York, London, Washington, Berlin, Milwaukee, Houston, Sheffield, and Hull	n/a

Source: Siemiatycki (2013).

stadium design has changed from the classic era of downtown brick, concrete, and steel stadiums with natural grass fields, to the modern period of large suburban municipal fields that were multipurpose and had artificial turf playing fields, to a more recent wave of "retro" ballparks that were located in downtown locations and reimagined the classic stadium design aesthetic.

The opening of the retro Camden Yards in Baltimore in 1992 sparked the most recent innovation wave of building retro baseball stadiums. Since that date, twenty-three of thirty teams have built new stadiums using the retro design style, meaning that this current wave of innovation has nearly reached its saturation point. Many of the current wave of retro ballpark projects cost hundreds of millions of dollars or even more than $1 billion as they incorporated increasingly complex features such as retractable roofs, and received public subsidies which were approved by both Democratic and Republican governments. In a number of instances, projects seeking to emulate the Camden Yards experience had large cost overruns and have failed to deliver on forecasted benefits in terms of economic development, local urban regeneration, or long-term increases in fan attendance. Nevertheless, Figure 3.2 shows the power of a wave of innovation across history: once a new ballpark design standard became in vogue, every single subsequent ballpark to be constructed over the subsequent two decades followed that style of design.

Intriguingly, this wave of retro stadium design at the turn of the twenty-first century has not extended beyond North American baseball parks. Globally, modern architecture and design has been the most common aesthetic for new stadiums constructed

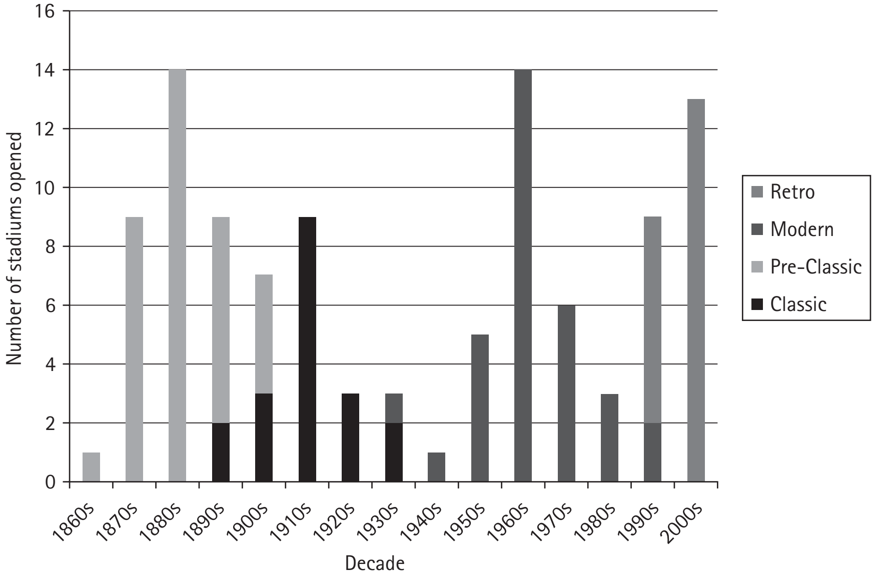

FIGURE 3.2 Number and type of Major League baseball stadiums constructed, 1860–2010.
(Source: http://www.ballparksofbaseball.com.)

during this period, even when they are designed by the same global architecture and design firms that worked on the retro baseball parks in North America. This suggest that the confluence of factors that has driven the retro stadium trend is particular to North America (and perhaps even more specifically baseball in America), and may be rooted in national economic and cultural conditions that are not necessarily transferrable elsewhere or to other sports.

3.2.2 Innovation Cycles Transcend Political Systems

The case of urban tram or streetcar systems provides an example of the diffusion of a technological innovation around the world to jurisdictions that have vastly different political systems, governance structures, and urban forms. This showcases how a single technology can serve to address a common global challenge, in this case the demand for mass urban mobility, in vastly different places. It also demonstrates the importance of symbolic messages. During a two-decade period at the turn of the twentieth century, urban trams were built in cities on five continents, including New York and Chicago (strong mayor, federalist democracy), Toronto (weak mayor, federalist democracy), London (unitary democracy with strong involvement of the national government in urban policy), Budapest and Sarajevo (Austro-Hungarian Empire), Calcutta and Alexandria (British rule of India and Egypt, respectively), and Rio de Janeiro (Portuguese colonial rule of Brazil). This rapid spread of trams was followed by the widespread abandonment of the technology in the mid-twentieth century. Streetcars were removed from the streets of almost every city in the world as they became increasingly unprofitable, viewed as part of the old urban order, and an impediment to the modern free flow of the private automobile. In the United States, the demise of streetcars was expedited by competition from urban buses, which was exacerbated by a conspiracy on the part of National City Lines corporation and its backers General Motors, Standard Oil, and Firestone Tire to create a bus monopoly in the urban transit industry (Mees 2010).

In the past quarter century, however, there has been a resurgence in the popularity of trams. Rebranded as light rail, tram systems costing hundreds of millions or billions of dollars have been built in dozens of cities globally. These tram systems are commonly promoted as a strategy to provide sustainable urban mobility alternatives to the private automobile, spur urban regeneration and smart growth, and attract creative industries and workers. Many of these new tram systems have faced significant challenges with construction cost overruns, delays, low ridership, and mixed evidence about whether they actually deliver development and environmental benefits (Pickrell 1992; Flyvbjerg 2007). Yet the wave of development has persisted despite the withering critiques. Light rail lines have been ascribed with a set of powerful symbolic meanings that transcend their tangible benefits, connoting messages of sustainable development, visionary leadership, and pride of place. The successful communication of these symbolic messages has enhanced the public popularity of light rail technology and lengthened the duration of this wave of investment.

3.2.3 New Technology Meets a Global Market

Super-tall skyscrapers provide an example of a class of megaproject that has surged in popularity as technology has evolved and it has been transposed to an eager market around the globe. As of 2015, there are ninety-two super-tall skyscrapers worldwide that are over 300 meters high—the common cutoff used to identify the tallest of the world's tall buildings (Council on Tall Buildings and Urban Habitat 2015). As shown in Figure 3.3, super-tall buildings are in the midst of a major surge of development. In the five years from 2010 to 2015, more super-tall buildings opened worldwide than in the previous eighty years, from the time that the first one was inaugurated. And super-tall buildings are growing taller than ever: between 1930 and 2000 the world's tallest building grew by 133 meters to 452 meters; and since 2000, the tallest building in the world grew by a further 377 meters to 828 meters. A closer examination of super-tall buildings illustrates how the confluence of technological, geographic, and economic factors has supported the boom in their development.

In their initial incarnation, super-tall skyscrapers were exclusively an American phenomenon. The first eight buildings over 300 meters tall were built between 1930 and 1989, and all were located in the United States. Until the 1980s, steel was the main structural material used, and super-tall skyscrapers were used for office towers. Classic buildings like the Chrysler Building and the Empire State Building in New York, and the Sears Tower (now Willis Tower) and the John Hancock Center in Chicago, came to be iconic

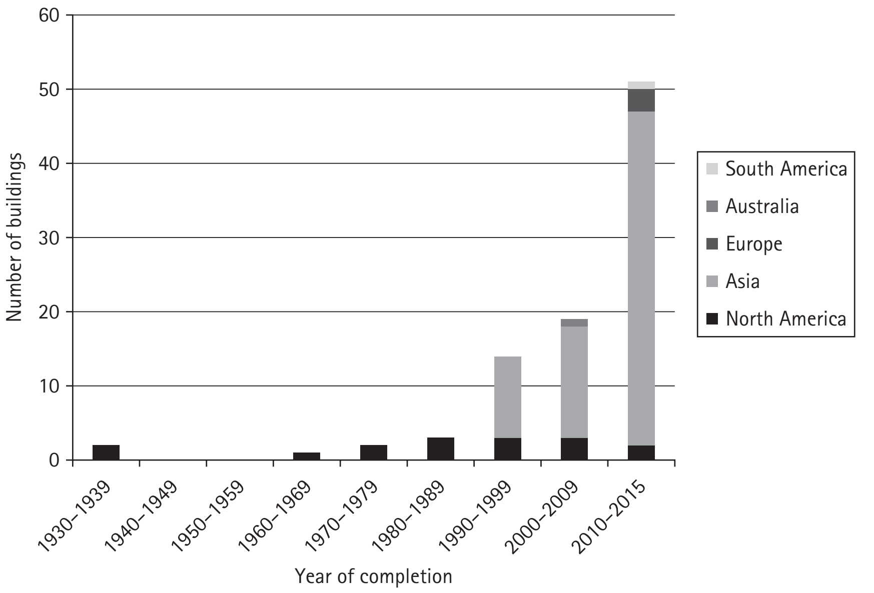

FIGURE 3.3 Global development of super-tall skyscrapers.
(From Council on Tall Buildings and Urban Habitat, 2015.)

features of their city skylines and important symbols of American engineering and business prowess. Thus while the technology existed to build super-tall buildings as early as the 1930s, very few were actually constructed, and there was not a market outside the United States.

The surge in super-tall building construction that began in the 1980s and really picked up in the 2000s coincided with three trends. First, new construction techniques have been developed to build super-tall buildings using concrete or composite structural materials. These materials allow the buildings to be built taller while maintaining a slender base, which makes them more economically viable, as there is not a very large podium that can be difficult to find tenants for. Innovative elevators have also been developed to move people more quickly through taller buildings. Second, super-tall buildings are now widely used for luxury residential or hotel uses, creating an entirely new market for tall buildings alongside offices. Third, super-tall buildings have become a global phenomenon, with the most rapid growth concentrated outside the United States in a handful of countries in East and Southeast Asia and the Middle East. In particular, the largest building boom has been in China and the Emirates of Dubai, which now are respectively home to 37% and 23% of all super-tall buildings. In these countries, super-tall buildings with iconic architecture have become important symbols of ascending global power and status—part of a luxury property-led economic development model, and a form of city marketing and branding. As such, the twenty-first-century boom in super-tall buildings globally reflects an adaptation of their American antecedents based on new building technologies and the construction of locally sensitive symbolic narratives in emerging markets.