CHAPTER 1

Megaprojects—Creators and Destroyers of Capital

Megaprojects are important in the grand scheme of things. Industrial megaprojects provide most of the things necessary for life on a planet with 8 billion humans and counting: energy, metals, chemicals, pharmaceuticals, seeds and food. When the projects are done well, they accelerate economic development and security. But it is also no secret that megaprojects are the most uncomfortable subject in the management of projects.

As a project management community, we have struggled to develop and execute these large complex projects with anything approaching consistent success. I first looked at these projects systematically in 1988 as a researcher at the Rand Corporation.[1] I found a story of large cost overruns on projects that were often delivered so late that their original purpose no longer existed. When I revisited the subject 22 years later, it was with a much deeper and better nuanced database that my colleagues and I had assembled through years of evaluating projects at Independent Project Analysis (IPA).[2] In that long interval depressingly little had changed. There was, however, a glimmer of hope in 2011 that was nowhere in sight in 1988: a number of large complex

[1]Edward W. Merrow et al., *Understanding the Outcomes of Megaprojects: An Analysis of Very Large Civilian Projects,* Santa Monica, CA: The Rand Corp., 1988.
[2]Edward W. Merrow*, Industrial Megaprojects,* John Wiley & Sons, 2011.

industrial projects were brilliant successes, a number far greater than two decades before. Those projects demonstrated that success was not a matter of luck or circumstance, but a product of deep and collaborative planning by the owners leading the projects.

In the 12 years since publication of *Industrial Megaprojects*, a great deal has changed. Today's world seems much further removed from 2011 than 2011 was from 1988. We have entered in earnest what promises to be a long crisis period around climate change. Renewables megaprojects have become common and will coexist with oil and gas projects and other megaprojects for years to come. All major projects in most parts of the world have to navigate the requirements of sustainability along with the mandate to be profitable. Local content requirements have proliferated and become increasingly complex in the past decade. We have lived through our first global pandemic in a hundred years, which changed both the projects landscape and geopolitics in profound ways.

The world is much more connected today than in 2011. The greater connectedness has made Shaping of megaprojects more challenging. The amount of information and disinformation available today dwarfs 2011. In 2011, the remarkable term *alternative facts* had yet to be coined, although the underlying concept was surely known. And in 2011, artificial intelligence (AI) was talked about but in much the same way we talk about space travel today.

There are more megaprojects today than ever before. Projects have increased in size and complexity for a number of reasons: easily accessed resources close to markets have largely been depleted; international oil companies must venture into deep water and other difficult environments because national resource holders control more easily developed oil and gas; chemical companies seeking lower cost feedstocks need to exploit economies of scale to compete globally, and often must go to the source of the feedstocks to make the project viable. The need for extensive infrastructure development means that many projects will have to be very large to spread the infrastructure costs over a wide enough base of beneficial production to be economic.

The efforts to control climate change, which are just beginning, have already given rise to a great many megaprojects and will give rise to thousands more if the efforts are successful. Many of the megaprojects aimed at climate change mitigation have already encountered

significant problems, especially with regard to economic viability and stakeholder alignment. If, as a projects community, we do not learn quickly how to do these projects well, efforts to slow planetary warming have little chance of success.

As the projects have increased in size and complexity, they have become much more difficult to manage. Cost overruns, serious slips in completion schedules, and operability problems have all become more common. Many of these very large projects end up being disappointing to their sponsors; a fair number turn out to be massive destroyers of shareholder wealth; and a few are horrendous with respect to anything and everything involved: the investing companies, the local population, and the environment. When megaproject disasters become public knowledge, which is rarely the case, they damage reputations and even jeopardize continued existence.[3]

IPA's research program on megaprojects over the past 20 years shows clearly that most of the poor results of these projects constitute self-inflicted wounds. The sponsors are creating the circumstances that lead inexorably to failure. *And that is profoundly good news!* What we do, we can fix.

Who Should Read This Book?

Anyone with responsibility for large, complex, or difficult capital projects will find things of interest in the pages that follow. My particular goal is to help those who sponsor, direct, or work on large projects guide the projects to safe and successful outcomes. Although my focus is on industrial megaprojects, very large projects sponsored by the petroleum, chemicals, minerals, power, and related industries,

[3]The failure of BHP's Hot Briquetted Iron Project in 1999 contributed to the company losing over half of its market value. The $10 billion plus overrun of Shell Sakhalin-2 project damaged Shell's reputation and created an excuse for the Kremlin to nationalize a large portion of the project. The structural failure of BP's Thunderhorse semi-submersible platform in 2005 in the U.S. Gulf of Mexico was an important element in a series of stunning setbacks for the company. Most megaproject disasters, however, remain carefully private—while sometimes wearing a very different and well-contrived public face.

those working on large public infrastructure projects should find the discussion relevant to their work.

Anyone interested in complex projects, even if they fall far short of megaproject status, will find the story of these projects informative to their situation. Most of the basic principles of doing megaprojects well are the basic principles of doing all projects well. Small complex projects often behave more like megaprojects than their small project cousins. If the reader is interested in projects generally, megaprojects will always be fascinating.

I very much hope that members of boards of directors of companies that sponsor megaprojects will read this book. To be blunt, when it comes to the governance of large projects, most boards strike me as brain dead. They are not asking the right questions and they are not asking questions early enough in the process to deter bad decisions.

Those who finance major projects should find a great deal of interest (forgive the pun) in the book. In many respects, this book is all about large project risk, which is a key concern for banks and others involved in project finance. It is my observation that bank financing often increases cost while doing nothing whatever about project risk.

Those who are concerned about the management of the modern publicly owned industrial corporation and teach others about how it should be done will also find this book interesting, and perhaps, very disturbing. The failure of these projects is symptomatic of the core problems of the modern firm: too much out-sourcing of key competencies, poorly informed decision-making, a woeful lack of accountability for results, and a pathological focus on the short-term at the expense of the long-term health of the corporation and its shareholders.

What Is an Industrial Megaproject?

The projects that are the subject of our research are a subset of all projects and even a subset of large projects. We focus on *industrial* megaprojects. By *industrial*, we mean projects that make a product for sale, for example, oil, natural gas, iron ore, nickel, gold ingot, diamonds, high-volume chemicals, and so on. All of the projects under

scrutiny were intended to make an economic profit, at least eventually, for some if not always all of the sponsors.[4,5] By confining ourselves to industrial projects, we have excluded several classes of important projects: military developments, purely public works and transportation projects, monuments, works of art, and so on. By excluding these sorts of projects we have excluded some megaprojects from our analysis. We have a couple of reasons for doing so:

- Confining ourselves to projects that are intended to make money simplifies the task of assessing outcomes, while not necessarily simplifying the range and complexity of objectives in the projects. Although it is true for almost all of our projects that *someone* wanted and expected to make money on the result, it does not follow that *all* of the sponsors expected to make an economic profit. Some were motivated by jobs creation, political ambition, general economic development, and other "public" goals. These "mixed motive" projects, as we call them, are an interesting class and pose challenges for "for-profit" sponsors.
- Having some economic profit motive disciplines and constrains the objectives of the projects in important ways. Some public works projects have objectives that are hard to fathom by mere mortals. Some military acquisition programs appear to continue almost solely on the strength of political patronage long after the military rationale has become obsolete or discredited.[6] And some "prestige projects," such as the *Concorde* supersonic

[4]A few of our projects were undertaken with the explicit expectation that they would make little or no economic profit, but would facilitate highly profitable projects later. These projects bear the dubious title "strategic," a subject to which we will return when discussing project Shaping.

[5]The term *sponsor* will be reserved for those organizations that claim formal ownership of a project by virtue of their economic investment in the project. Those investments could occasionally be in-kind or deferred, but usually indicate monetary investment in the cost of the project.

[6]For example, the U.S. Air Force B-1 Bomber program continued long after a superior option had emerged due entirely to political influence. "B-1 Problems, If Reparable, Could Cost $3 Billion," *The Boston Globe*, February 13, 1987. The V-22 Osprey aircraft program not only overran its budget colossally, but also suffered repeated crashes, but continued anyway. "Assessments Needed to Address V-22 Aircraft Operational and Cost Concerns to Define Future Investments," GAO-09-482, May 2009.

transport, have objectives that must forever be in the eye of the beholder. Who is to say whether prestige has actually been enhanced and was it by an amount sufficient to justify the opportunity cost of the project? Industrial projects tend to have at least some nicely tangible objectives.

What makes an industrial project an industrial *mega*project? Megaprojects, as the name implies, are very large. We start considering a project in the megaproject class at about $1 billion in today's terms. This is slightly more relaxed on the low side than the definition used in the first edition of *Industrial Megaprojects*. I decided to make the change because using the $1 billion threshold, there is no relationship between size and success or failure[7] (to be defined in the next chapter). If we include smaller projects, success becomes negatively related to size.

Why Study These Projects?

There are four compelling reasons to study and understand megaprojects:

- There are many more of them than in times past and this will continue for decades to come.
- These projects are important. They are important to the societies in which they are being done; they are important to the health of the global economy; they are important to the sponsors and others putting up huge amounts of money.
- These projects are very problematic. They are failing at an alarming and unsustainable rate.
- There is not much published that speaks directly and quantitatively to the types of projects considered here.

I will discuss each of these reasons to worry about megaprojects in turn.

[7]The statistical relationship is close to null (Pr.|z|<.81).

Increasing Numbers

Industrial megaprojects have become much more common. For much of the 1980s and virtually all of the 1990s there were few very large projects, even in the petroleum industry. The Norwegian and U.K. North Sea had been home to a number of megaprojects in the 1970s. These projects had a very difficult go, and without the rapid rise in crude oil prices in the wake of the overthrow of the Shah of Iran, almost none of the megaprojects in the North Sea would have been profitable ventures.[8] Most of the megaprojects that had been in planning stages in the late 1970s died abruptly when commodity prices fell in the early 1980s.

However, a number of factors have converged to make megaprojects much more common in the first decades of the 21st century, and these factors give every indication of being enduring drivers of very large projects. The first factor driving the current wave of megaprojects has been the rapid rise in the demand for almost all major commodities; iron ore, coal, copper, and petroleum have all experienced very rapid increases in demand (and therefore, price) since 2003. Previously, most prior commodity price fluctuations had not been synchronized; prices might rise for one or two metals, oil and gold prices might rise for political reasons, but not all at the same time. The underlying common driver this time was the rapid industrialization of China and India in the context of reasonable overall global growth. None of the major commodities are actually facing imminent global depletion; however, most are facing upward sloping long-run marginal costs.

The different commodities have had somewhat different drivers for large projects:

- Opening up a new major mineral ore body has long been expensive. Most major new mines today are in places that require major infrastructure development to be practicable. When a good deal of infrastructure is needed, the production volume must be very large to spread those infrastructure costs across a broad enough

[8]G.R. Castle, "North Sea Scorecard," Society of Petroleum Engineers Paper 15358, October 1986.

base for the venture to be profitable. This makes large size the only avenue to development, not an option. Today, a good many megaprojects in mining are driven by the "energy transition metals," that is, those required to sustain efforts to mitigate climate change: copper, nickel, cobalt, lithium, and rare earth metals.

- Crude oil is a special case, at least partially. A large portion of oil that remains relatively inexpensive to produce is held by state companies.[9] In order to stay in the oil business, international companies have been pushed quickly into places where oil is difficult and costly to develop, usually deep water. International companies also have gained access when reservoirs are difficult to produce, for example, offshore heavy oil production in Brazil, very heavy oil onshore in Venezuela, the very sour oil and gas reservoirs in the Caspian area, or the very harsh climate off the eastern Russian coast, or in inaccessible areas such as central Africa. As a consequence, the marginal capital costs of production have increased very rapidly for these companies. This translates into a dramatic increase in the number of international oil company megaprojects.
- Rapid changes in the global economy have driven basic chemical companies to shift more of their manufacturing to fast-growing Asian economies. They have also sought to gain feedstock cost advantage by moving manufacturing to countries offering feedstock at below world open market average prices to attract production facilities, mostly in the Middle East.[10]
- A wide variety of megaprojects are being spawned by climate change action: carbon capture and sequestration, nuclear reactor projects, including small modular reactors, wind and solar renewable power, and various forms of hydrogen and hydrogen-to-carrier projects.

[9]Estimates of world reserves held by national oil companies range between 75% and over 90%. See, for example, *Wall Street Journal*, May 22, 2010.

[10]High natural gas prices continue to push much basic chemical manufacture out of Europe and into the United States where natural gas from shale provides low-cost feedstocks. Natural gas prices control the prices of ethane and propane, which are feedstocks for building block commodity chemicals such as ethylene and propylene.

Megaprojects Are Important

Without the industrial megaprojects in the extractive and manufacturing sectors, global competition for resources, which is already very intense, would become unmanageable. While one can reasonably question whether extractive projects have been a net boon for less developed economies that hold large supplies, one cannot doubt that the overall megaproject effect on global economic growth has been substantial. Megaprojects are responsible directly and indirectly for millions of jobs around the world, and without the many megaprojects we have seen over the past decade, global prices for virtually all major commodities would be much higher with all the attendant economic dislocation.

For the sponsors of megaprojects, success or failure of the project can mean the success or failure of the company. For all except the largest oil companies, a serious failure of a megaproject puts the company's future in jeopardy. Megaprojects are increasingly seen as essential to being competitive, but in many cases, the skills needed to effectively develop and control these projects have not developed in tandem with the need.

It is also important to remember that the success or failure of these projects is often critical to the societies in which they are developed. Megaprojects place a good deal of stress on local communities. When they fail, and especially when they fail completely, the local communities suffer irreparable damage.

Megaprojects Fail Too Often

Megaproject results are frequently seriously short of the expectations of the sponsor-investors. Their cost overruns are often so significant that the whole project becomes NPV negative.[11] Their schedules often slip and early-year operability, which has a disproportionate effect on profitability, is frequently very poor. Occasionally, the projects produce environmental disasters as well. As we will show, these results are not

[11]*NPV*, of course, refers to *net present value*, which is a measure of the economic returns from an investment with future profits discounted for the effects of time.

inherent in the nature of the activities. They are, instead, caused by human decisions, ignorance, and uncontrolled but controllable human failings. These projects can be fixed.

The Literature Is Sparse

This book is needed because, despite the many thousands of pages written on the management of projects, very little of the literature addresses the peculiar nature of very large and complex projects as a class. There are some notable exceptions. Morris and Hough explored a set of eight very large public and private projects in 1987.[12] Like me, they concluded that the success rate is quite disappointing. I build on their path-breaking work. Miller and Lessard[13] and their colleagues explore what they call "large engineering projects," focusing on the development of new institutional arrangements. Their discussion of the process by which turbulent project environments might be settled is a key starting point for our own discussion of the Shaping process in Chapter 5. We focus much less on the creation of new contractual forms, such as build-own-transfer (BOT) simply because we have seen very few of these "new institutional arrangements" actually function as advertised. Our data, which are considerably deeper than that found in Miller and Lessard, flatly contradict the effectiveness of certain arrangements, such as incentivized contracts, which they tout as successful.

Flyvbjerg, Bruzelius, and Rothengatter make the most recent major contribution to the megaprojects literature, focusing primarily on very large infrastructure projects executed by the public sector around the world.[14] Although I share some of the same conclusions about these projects, public infrastructure projects are, in many respects, quite different than the projects explored in this research. Public infrastructure projects share many of the pathologies common in other publicly funded projects, such as military acquisition. They are frequently beset

[12]Peter Morris and George Hough, *The Anatomy of Major Projects*, John Wiley, 1987.
[13]Roger Miller and Donald R. Lessard, *The Strategic Management of Large Engineering Projects*, Cambridge, MA: MIT Press, 2000.
[14]Bent Flyvbjerg, Nils Bruzelius, and Werner Rothengatter, *Megaprojects and Risk: An Anatomy of Ambition*, Cambridge University Press, 2003.

by a phenomenon known as "buy-in and hook" in which low costs are promised early, knowing full well that the eventual costs will be much higher. While this sort of deception is not unknown in private sector ventures, it is not very common, simply because there is usually no taxpayer available to foot the bill later. As we will discuss later, many of the core conclusions of the "Oxford School" of megaprojects are highly inaccurate when applied to industrial projects.

The Organization of This Book

I have organized this book into five parts.

- Part 1 introduces the IPA megaprojects database and describes the research process that underpins this book. I seek to provide enough about methodology to satisfy the methodologically oriented reader without boring others to a stupor. I then present the track record of industrial megaprojects, summarizing the 760 large and complex projects studied to date and exploring trends in megaproject performance in the 21st century. To conclude Part 1, I describe the mechanisms by which projects fail and the narrower pathway to success.
- Part 2 is devoted to the three streams of work that must be completed and synchronized successfully by the sponsoring companies to produce a successful project. I devote three chapters to various aspects of the "Shaping" process, which is the least well-articulated and understood of the work streams. This section deals extensively with what Miller and Lessard[15] call the "Shaping" of megaprojects. It focuses on some brilliant examples of business leaders making an inherently unstable environment strong enough to permit a successful megaproject to be executed. But it also focuses on the decisions that business managers make that have devastating consequences for their projects without their ever fully understanding what went wrong. The business sponsors of large projects should really focus on the Shaping discussion

[15]Miller and Lessard, 2000.

because it should be their work stream. Project professionals need to read about Shaping to understand how they got into this mess and what they might do in the future to elevate problems to corporate management when mischief is being created by their business bosses.

Then we turn to the acquisition of the Basic Data, that is, the technical information underpinning design of the project in Chapter 9. Errors in the Basic Data are the quickest route to a project that does not operate as intended. As I was tallying up the causes of failure in these projects, I was surprised to see the number of times that Basic Data problems occurred. Because the Basic Data development often needs to start long before the project gets fully going, the Basic Data chapter should be read by the business professionals who often control the funding for Basic Data development, and by the R&D and technical specialist community that often do not consider themselves part of "project management" but who usually do the Basic Data development.

The project work stream up to authorization, which I call front-end loading (FEL), is discussed in Chapter 10. The discussion of the project work stream is written more for the project professional. It focuses not just on what needs to be done to make these big projects successful, but *why* those things are crucial. Many of the practices required to generate successful megaprojects are resisted by business management because they are apparently expensive and time-consuming. When the project team understands why certain practices are critical based on the actual history of megaprojects, they are better able to persuade reluctant managements to do the right things.

- Part 3 is all about people. First, we discuss the key players on the owner management side. Owner teams and owner team organization models then follow. I have also added some discussion of desirable attributes of own project organizations to support megaprojects.
- Part 4 is entitled "Getting It Done" and focuses on contracting for the engineering and construction services that will be essential to executing the megaproject, and then I discuss the control of risk in execution.

- Part 5 discusses the critical role of governance in making successful projects and then some summary conclusions about where to go from here.

Respecting Confidentiality

Some of the readers (I sincerely hope) will have been directly involved in the megaprojects that underpin the conclusions of this research. When I have offered examples, I have tried to select cases that are not unique, and in some cases, I have masked them enough to ensure that no individual project for which we have conducted a closeout evaluation can be identified conclusively. This is necessary to meet our obligations of confidentiality to the people and companies involved. When any project is mentioned by name, it is based solely on publicly available information.

If you are certain that I am discussing your project in a particular example, let me offer this caveat: several years ago, I wrote a volume of 20 case studies of new technology projects for the DuPont Company. Many of the projects had disastrous outcomes and some were brilliant successes. In the introduction, I carefully explained that *none* of the projects summarized in the volume were DuPont projects because the DuPont new technology projects would be covered in a separate volume. Nonetheless, for the next six months I had DuPont business and project professionals stop me in the hall while I was visiting the company and comment something like this: "You did a pretty good job summarizing my project, but you got a couple of the details wrong. . . ." This reflects a well-known fact: we humans have been making a hash of projects for a long, long time.